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JANUARY 2016
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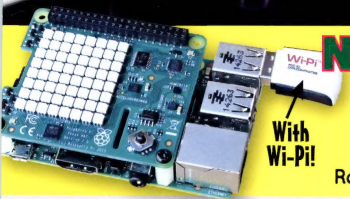
QUICKBRAKE . . .

Vital extra time to stop nose-to-tail prangs



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- PCB: 78 x 49m

Kit includes quality solder masked PCB with overlay, case with screen printed lid and all electronic components.

Contents

Vol.29, No.1; January 2016 www.siliconchip.com.au

Features

12 Blood Pulse Oximeters: How They Work
Ever visited someone in hospital and noticed a small sensor clipped over one of their fingers? That's the business end of a blood pulse oximeter, used to monitor the oxygen level in a patient's blood. Here's a quick run-down on exactly what they do and how they work – by Jim Rowe

76 Versatile Technology: An Aussie Innovator
Who said the Australian electronics industry was dead? One innovative company, Versatile Technology (Melbourne), has become a world leader in making equipment for testing metal soft-drink/beer cans and other containers such as PET plastic bottles – by Ross Tester

86 Handy Reactance Wallchart
This handy wallchart lets you easily check the -3dB rolloff point of a simple RC or RL network or find the resonant frequency of an LC network

Projects To Build

18 Raspberry Pi Temperature/Humidity/Pressure Monitor Pt.1
Want to monitor temperature, humidity and pressure using a web browser from a remote location? Here's how to do it using a Raspberry Pi 2 Model B computer, a Sense HAT module and a Wi-Pi WiFi dongle – by Greg Swain

28 Valve Stereo Preamplifier For HiFi Systems
This stand-alone stereo valve preamplifier offers good performance, with low distortion and a very high signal-to-noise ratio of -105dB. It's easy to build too, with the preamp and power supply all on one PCB – by Nicholas Vinen

36 High Visibility 6-Digit LED GPS Clock, Pt.2
Our new GPS high-visibility 6-digit LED clock automatically changes time zones as you travel around the country or even between countries. This second article has all the information you need to complete and use it – by Nicholas Vinen

54 Reduce Rear-End Collision Risk With The QuickBrake
Reduce the risk of rear-end collisions by automatically switching on the brake lights each time you rapidly lift off the accelerator – by John Clarke

Special Columns

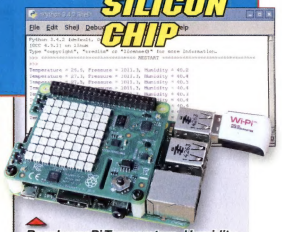
62 Circuit Notebook
(1) USB Power Injector; (2) Bi-Directional 8-Bit Digital Interface; (3) Audio Generator Has Triangle & Square Waveforms

66 Serviceman's Log
Tools, old scopes & my hoarding habit – by Dave Thompson

82 Vintage Radio
Sony's TR-63 shirt-pocket transistor radio – by Ian Batty

Departments

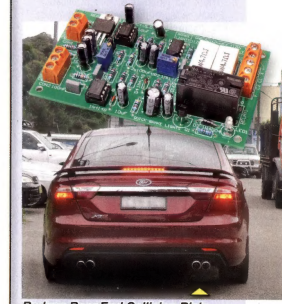
2 Publisher's Letter
4 Mailbag
53 Product Showcase
89 SC Online Shop
91 Ask Silicon Chip
95 Market Centre
96 Advertising Index
96 Notes & Errata



Raspberry Pi Temperature, Humidity & Pressure Monitor – Page 18

Valve Stereo Preamplifier For HiFi Systems – Page 28.

High-Visibility 6-Digit LED GPS Clock, Pt.2 – Page 36.



Reduce Rear-End Collision Risk With The QuickBrake – Page 54.

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Publisher's Letter

QuickBrake: an idea whose time has come

This month, one of our featured projects is the QuickBrake which has the potential to substantially reduce the incidence of rear-end collisions. Now you might not think that is a big deal but there are Australian statistics which indicate that some 26% of all road accidents are rear-end collisions and almost half of those result in injury. Any device which can substantially reduce those statistics must be very worthwhile.

And yet, this idea is not new. In fact, this month's article is our second version of this project, having been first featured in the March 2004 issue, 12 years ago. This second iteration is very similar to the first, with the major change being to make it able to be used if the brake lights are changed over to LED equivalents when it is installed.

So how does it work? It senses when you are about to make an emergency stop because you lift off the accelerator much more rapidly than when you are about to make an ordinary stop. It does this by monitoring the voltage from your car's throttle position sensor (TPS) which is normally a potentiometer coupled to the accelerator pedal at its pivot. Without going into the description (you can read it on pages 55 & 56), the circuit senses the rapid change of the TPS voltage and uses it to briefly operate a relay whose contacts are in parallel with the brake pedal switch contacts.

So the QuickBrake circuit switches on the brake lights even before your foot has actually left the accelerator and moved over to depress the brake pedal. Typical driver response times, having realised the need to make an emergency stop, are from 250 to 750 milliseconds. So even if we allow that the QuickBrake turns on the brake lights some 250ms before you can manage it, that is a major safety improvement.

If the following driver is travelling at 110km/h at the time your brake lights come on, that gives him (or her) more than a car length extra to come to a full stop. That could be the difference between a safe but panic stop for the following driver (and possibly some heavy breathing afterwards) or perhaps a severe accident and injuries. Even if the following driver does not manage to stop in time, the resulting prang should be less severe than if the early warning did not occur.

Now if you are driving a largish modern car with active head restraints you might not be too worried about the consequences of a rear-end collision. Don't be so complacent. A few years ago my Honda Accord was subjected to quite a severe rear-end collision. I was stopped at traffic lights and heard the screech of tyres from a car behind me. A glance in the mirror showed it approaching rapidly with smoking tyres. I knew it would be a severe collision and there was nothing I could do about it. I was a sitting duck.

In the event, I was not injured but the driver in the car behind was – severely. Fortunately for the injured driver, the accident happened outside Mona Vale Hospital. But I was very lucky and the outcome could have been much worse. I could have been killed, you see, because my car was booted right across the intersection, into the path of cars coming in from the right. The gods must have been smiling on me that day because my car was not T-boned and the only damage was to my car's rear bodywork. The other car would have been a write-off.

I report this because I intend installing the QuickBrake on my car. While I very rarely need to make an emergency stop, I like the idea of giving a following driver more warning. And think about this; if you do have a collision but you have the QuickBrake fitted to your car, that might mean that your accident is not made much worse by a pile-up in the rear.

Leo Simpson

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(*) Optional, please contact sales for more details.

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MAILBAG

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Fingerprint Access Controller will not work for everyone

With respect to the Publisher's Letter in the November 2015 issue, I have a simple question for Leo Simpson: did the SatNav tell you its speed and direction as it left the car? I just had to ask!

The Fingerprint Access Controller in the same issue is a nice project but from my experience I would never recommend that type of system. My previous employer changed from using access code to fingerprint recognition for sign-on and sign-off. This worked well except for myself and another employee. Neither of us could get reliable recognition and eventually both of us were allowed to use an access code.

The reason was that every finger and thumb was badly marked from a lot of manual work. The fingerprints were continually being worn away or so badly obscured by cuts and abrasion that there was no consistently recognisable pattern.

The article on the magnifying devices was interesting but one of the most common devices was missing; a jeweller's loupe. They are readily available and I have been using them for over 20 years. Their only problems are the skill needed to hold them on the eye and the fact that they fog up when cold.

George Ramsay,
Holland Park, Qld.

Leo Simpson comments: as a matter of fact, I was running with cruise control at 110km/h, as checked by the SatNav itself – I doubt whether it registered the change of direction or speed as it left the vehicle, since SatNavs generally take a few seconds to register that sort of info on the display. I wonder if it registered the fact that it had made one silly mistake too many . . . ?

I use a jeweller's loupe to examine objects close up but they are no good when you are actually trying to solder components.

GPS SatNav problems in Europe

I've just been reading the latest SILICON CHIP (November 2015). The Publisher's tale of woe with the GPS rings a bell. I have an older cheap Uniden one that is not too bad, most of the time. I do know my way around pretty well, so it's not a massive problem when it confuses itself.

However, last year I drove a Eurolease Peugeot 208 for a few weeks around Europe, which is an excellent deal by the way. It was a brand new vehicle with a factory fitted GPS. Most of the time, it was helpful but from time to time, it just "lost the plot" taking me in convoluted circles or triangles, or random shapes.

Even more disconcerting was its habit, on at least four occasions, of directing me to "turn left in 300 metres". Once was on the autobahn while at about 130km/h and at other times it was in an old part of a city, where it appeared that the houses had been there for about 200 years, and no sign of a road.

This might have been tolerable if it was a 10-year old aftermarket-unit, but a brand new factory fit? No, it seems to me that Peugeot and probably others, need to pay attention to their software.

Barry Lennox,
Christchurch, NZ.

Partial solution to AM radio interference

I have an old house with a sitting/dining room that lends itself to the storage and use of four of my valve radios, the youngest being a 1940s Mullard. I alternate and listen to each radio in turn at breakfast every morning but also had the same problem as Jo Scheiffers (whose letter was featured in the Mailbag pages of the November 2015 issue) with a high amount of noise swamping the AM broadcast band.

Recently, I invested in four inexpensive Tecsun loop antennas, as advertised on page 5 of the December 2015 issue. I did not expect miracles as the radio designers decades ago could not have envisaged the EMI that we generate constantly in our homes today; radios were simply not designed to reduce a non-existent interference.

There were no miracles but the results were pleasing, with a worthwhile reduction of noise accompanied by a small RF gain. I now find the radios a pleasure to listen to and this well justified the purchase of the loop antennas.

Paul Walsh,
Montmorency Vic.

Grid-connected solar systems don't have enough panels

I recently purchased a house that was fitted with a grid-connected solar PV system. It seemed very inefficient to me and I decided to see if I could work out why. What I discovered was that the west-facing PV array was sized such that it could rarely if ever deliver sufficient energy to the inverter to enable it to produce its rated power output. In the winter months, it didn't stand a chance! Much of the capacity of the inverter was being wasted and hence the inefficiency.

There has been considerable comment in your magazine on the misuse of the terms "power" and "energy" by people not "in the know". The reason that the situation above has occurred is I believe a prime example of this misuse. Industry, regulators and consumers alike have and are still being led astray by it.

The consumer PV marketplace at least is working on the assumption that the "best practice" design standard for PV systems requires that the rated output power of a PV array be matched (equal) to the rated invert-

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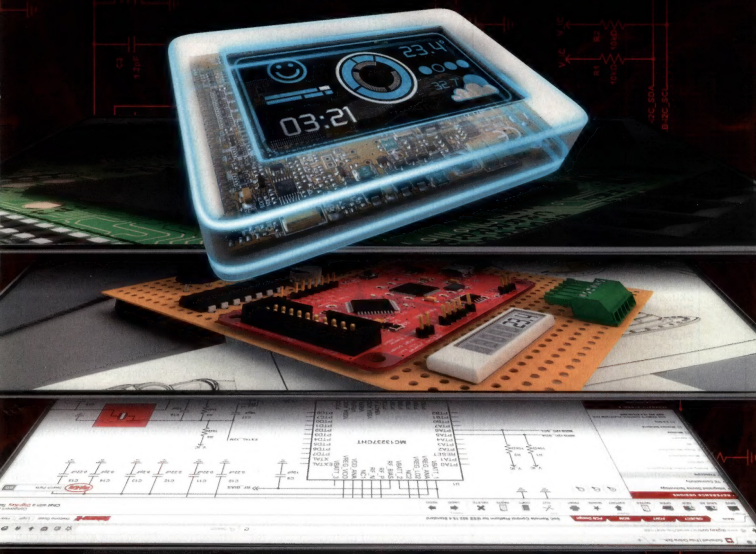

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Mailbag: continued

Some things have changed but some stayed the same

I studied electronics in high school and went on to complete a degree in the 1980s. My room was always full of EA and ETI projects under construction. Then job, family, school volunteer stuff etc came along and it all vanished until just recently.

When the kids finished school, I had some time on my hands and bought a copy of SILICON CHIP. Much to my surprise, the editor appeared familiar. Sure enough, a quick Google confirmed that it was the same Leo Simpson from my 1980s reading! Obviously Leo's experience has served him well because the magazine feels familiar to me, despite 25+ years out of the scene. After reading the issue I went out and subscribed for two years (and bought six back issues).

Being back into electronics for fun again is great. Seeing Leo Simpson at the helm left me feeling comfortable that some things on the planet are constant; albeit some things have changed, like having to buy glasses so I can see when soldering and tweezers for surface mount components. I now have several projects complete and half a dozen under way. Great magazine, keep it up!

John Mulcahy,
Leeming, WA.

er output power. Adjustments (about 33%) are allowed for temperature and other losses but ultimately the design approach is power matching.

Energy regulators and grid operators are even relying on this premise for the maintenance of electrical safety. There are no tests in the current and proposed Australian Standards (AS4777.2) to determine inverter performance in the event that the input energy available to the inverter is greater than it is rated to handle.

I did find articles promoting increasing the array size to improve energy output but this approach has attracted emotive labels such as "power clipping" and "array over-sizing". The former conjures up negative thoughts of harmonic distortion and the latter being in excess of manufacturers' ratings (like PC over-clocking). Neither of these has any technical credibility if the inverter is able to manage an energy level output from the PV array which exceeds what it needs to produce its rated power output.

Intuitively, one would think that a PV inverter capable of Maximum Power Point Tracking would automatically be able to do this but this apparently is not the case with some of the original inverters on the market. Many of the inverters on the market now have this capability as it is needed to enable to the grid operator to reduce inverter power output when the grid is being overloaded.

When I analysed my system, it was clear that the "power matching" criteria was the root cause of the inefficiency and that the solution was to increase the number of panels. Modelling demonstrated that for a north-facing array system, the energy output could be increased by about 87% for a 100% (or doubling) of the size of the array. A 50% increase would produce a 50% increase in energy! For east and west facing arrays, doubling the array size produces at least a 90% increase (the analysis has been independently verified).

To achieve this improvement, the inverter must be able to manage the excess energy that it is presented with around midday in the summer months. If the excess energy in summer is not being reaped then how are the efficiency improvements actually achieved?

Consider a typical bell-shaped curve for the power output of a PV array during a day. The energy harvested is the area under the curve, ie, power x time. Moving the curve upwards on the power axis increases the area and therefore the amount of energy harvested. Increasing the number of PV cells moves the curve upwards in the same way that increasing insolation does.

When the energy available from the panels exceeds that which the inverter can process, the inverter output power is capped at its rated value, ie, the top of the curve is flattened. The energy

loss at the peak is fully made up, in the 50% panel increase example, by the extra energy that is available either side of the capped region.

In the winter months when the inverter is not required to limit the output power, the full capacity of the additional panels is able to be harvested.

If "power matching" is not the correct design approach then what should it be? For a given annual energy harvest, I believe that the aim should be to find the combination of inverter and PV cells that achieves this for least cost.

The price per watt for inverters and PV cells is now approximately the same. Buying inverter capacity that is only used for short periods over summer does not make economic sense. Offering super-sized inverters should be labelled a consumer rip off! As a rule of thumb, a PV array kW output that is twice that of the inverter is a good starting point. The losses are relatively small (less than what consumers with east or west-facing installations currently experience) and it will have minimal impact on the payback period.

If the price per watt for PV arrays continues to fall then the number of panels as a percentage will need to increase and the capacity of the inverter reduced to achieve the least cost solution and, incidentally, one that provides a more uniform energy output over the full year.

When I tried to put my findings into practice in the form of an upgrade to my home system, I discovered some major impediments.

The "power matching" design concept is enshrined in the Clean Energy Council's (CEC) Design Guidelines document. The CEC manages the accreditation process for Installers and Designers under the Commonwealth Renewable Energy Act, or more precisely the Regulations. The CEC is an Industry body. Its membership is predominantly supplier organisations and grid-operators.

The Clean Energy Regulator (CER) under the Act manages the production and sale of Small Technology Certificates (STC) that effectively subsidise the purchase price of the PV panels and provides the grid operators with the means of meeting their renewable energy commitments.

For the purposes of obtaining STCs only, CEC accredited Designers and Installers must follow the Guidelines or risk de-accreditation if they don't. State-managed electrical safety aspects of the installation solely require an electrician's licence. Standards Australia documents cover the safety and design standards aspects but not the "power matching" concept.

Most suppliers that I approached would not consider anything other than straight power matching but one was prepared to supply the additional 33% of panels that is allowed in the

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Mailbag: continued

Dash cameras are very worthwhile

About three years ago, my family were run off the New England highway by a B-double truck, between Glen Innes and Guyra. It had crossed the double lines and was on the wrong side of the road and we were in a cutting with nowhere to go; a truly frightening experience. I decided then and there to buy a dash camera to capture any offending vehicle and its number plate.

On return from holidays, I went to Jaycar at Woolloongabba and forked out $199 for a dash-cam. Little did I know that this was going to be the best $199 I'd ever spent. It was on Good Friday 2014 about 9PM when we were wiped out by a car running a red light on the intersection of the Marshall Rd freeway off-ramp and Marshall Rd at Holland Park.

Both cars were write-offs and no one was seriously injured thanks to the safety devices in modern cars. After the other driver and I were breathalysed, the police set about interviewing to work out what happened. Since we were "T-boned" on the righthand side and I was the driver, I was at a disadvantage legally.

I was not that coherent after a hit in the head. Fortunately, the other driver admitted to going through the red light. Consequently, the police wanted me to swear on a stack of bibles that I had the green light. Then my daughter said, "Why don't you give the police the dash-cam". She went and extracted it and handed it to the police.

An hour so later the police arrived at the PA hospital emergency to return the dash-cam. They had smiles on their faces and said that I was "all in the clear" but that they might have to arrest me for the outburst of recorded bad language! I explained that I thought that this type of language was the exclusive domain of the local Ladies Catholic College and I must have subliminally learnt it from them! With that they laughed and wished us well!

Now to the point of all this: the dash-cam records everything, even speech. In this case, the dash-cam recorded a number of important things: the way I had been driving up until the crash, that I was slowing for the intersection, travelling below the speed limit and that the the light was continuously green.

Apart from my short "commentary" after the hit, the police suggested that I have a look at the footage which showed that I had actually stopped the car a split second before the impact. This meant that the impact was in-line with the east-west engine and it took the full force and we were saved from the impact being on the righthand door pillar.

The police also remarked that my reaction time was pretty good for someone my age and that this saved us from serious injury.

Neil Bruce,
Tarragindi, Qld.

Guidelines. Eventually, I did manage to find one that could see the way through the swamp and I have been delighted with the resulting upgrade.

Looking at it from a broader community perspective, the current design approach results in a very peaky energy output. It makes it difficult for consumers to use the energy they generate (they get next to nothing if they don't use it themselves) and for the grid operators to manage the peaks. In short, I am really starting to question the point of these systems and what will happen when the state government energy buyback subsidies come to an end, inverters fail or grid operators start shutting down inverters during peak production periods to protect the grid. A major change in the current technical and policy direction seems essential to me if these systems are to be sustainable.

Finally, I have a comment on battery-backed inverter systems for those who think that they may be the way to go in the future. The comment is derived from a somewhat simplistic analysis of what is being proposed for domestic systems that would not have sufficient battery capacity to enable consumers to disconnect from the grid.

The inclusion of batteries and associated charging systems adds considerably to the cost of the system. In areas already grid-connected, it is unlikely that it will be an economic proposition even if battery prices drop significantly.

Perhaps what is more alarming is that the energy needed to manufacture these systems is about the same as the energy that they will produce. The energy required to make the batteries is very significant and they require periodic replacement.

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If the grid-connected system situation is anything to go by, I despair that consumers will not be in a position to make informed judgements as to what is the best solution for them.

Steve Lansell,
Ardross, WA.

Off-peak battery charging with smart metering

Recently there has been much discussion about whether solar power is cost effective. I installed six square metres of solar panels a few years ago, so when I got my latest quarterly bill I thought I should check it. Here are the figures for our 2-person house:

Daily usage: 8.34kWh vs average 16.1kWh
Peak: 156.754kWh, $72.19
Shoulder: 310.364kWh, $56.22
Off Peak: 274.802kWh, $27.33
Supply Charge: $73.43
Buy back: 185.044kWh, $9.44

I will use these figures for an installation I have in mind, with battery storage and only off-peak draw for battery charge and usage. From the figures, I think I could arrange to charge a battery off-peak to supply all my usage. Off-peak time is from 10pm to 7am which should be ample time for recharge. The cost would be about $50 off-peak (per quarter). Taking the buy-back into account and allowing for the supply charge gives a cost of $125 a quarter, a saving of ~$75, say $300 per annum, covering an initial cost of, say, $5000 for the battery and control equipment.

This should be even more attractive for users with average, or higher, power demand. If many users adopted such a plan, the cost of electricity would have to rise, making the plan even better. However, the suppliers would protect themselves by changing the timing, so we could all have a bit of fun chasing things around!

Jim Jacobs,
Engadine, NSW.

More comment on GPS SatNav

With regard to the Publisher's rather bad experience with with his GPS SatNav, my Garmin GPS, brought at Dick Smith, is an example of good technology. Why did I buy this brand? It seems government agencies use the brand and it is mostly reliable. My overpriced model cost me over $475 without the ability to update maps without paying another fee.

At first I updated its software on my computer and while maps could have been paid for and updated, I refused at first as the cost was also a bit too pricey. They have dropped the price from $195 or so to less than $100 but I feel at the moment I do not need it as I live in the country and seldom go to the city.

I could have suggested an update for the Publisher's unit but will look for it one on the Hume highway instead. (grin!) Where exactly was it chucked? (only kidding). It's obvious to me that a software upgrade could have fixed it.

Yes, they are rather frustrating, with one local map still wanting me to take a deviation on a straight piece of road, which was changed years ago. The same happened when I went to see the Mt Piper power station. The GPS wanted me to turn, when there was no turn in sight. These kind of "mistakes" are quite often left in on purpose, to stop other commercial GPS manufacturers using their database, so if they show the same "mistakes" they obviously copied their mapping data.

Best regards to the Publisher and please try getting to grips with your GPS whose logic isn't easy to understand, and whose manufacturers are obviously blind to user need for easy-to-understand technology. Their menus are not kitchen-recipe simple and need user input for best functionality and to prevent the user ending up on a 4-wheel drive mountain track, something the manufacturers could have left out as a default setting.

John Vance,
Wangaratta, Vic.

Comment: updates don't normally help with false directions to turn off highways where no turns have ever been possible.

Google drone deliveries could be fraught

A day or so before reading the November Publisher's Letter on the issues with GPS SatNav units I saw a news feed that said the Google was pushing ahead with drone deliveries. Your letter made me wonder if the deliveries would use the same mapping technology, with all its prob-

Mailbag: continued

2-way versus 3-way loudspeaker systems

I saw the query about a motorised barrow in the Ask SILICON CHIP pages of the November 2015 issue. We had some garden-wall work done by a great stonemason from the Sunshine Coast in Qld – Chris Atkin – and he had a motorised barrow that he made himself, from parts sourced on eBay etc. I have had a look and there are many kits and components available, as well as fully built electric barrows.

In regard to the query about a 3-way version of the Majestic loudspeaker system (page 91), I totally agree with your comments. The performance figures shown in your test results are the answer in themselves. There are zillions of 3-way systems that are nowhere near as good as the Majestic.

It's not about 2-way or 3-way; it's all about design and implementation. If the enquirer is wanting to put his/her stamp on the system they build, then they need to go through a proper design process using any of the good software programs out there or Vance Dickason's Loudspeaker Cook Book etc. Some effort produces excellent results and can often avoid the uninformed hype that appears in some of the forum responses.

The foam surrounds are the worst as they oxidise to a dust after a few years and then any replacement is likely to have different characteristics and parameters and can invalidate the original design. A much better long-term answer is drivers with a neoprene or butyl rubber etc surround; almost anything but foam.

My own experience and that of our Brisbane Audio Group is that all foam surrounds fail after a few years and I am referring to over 40 years of building loudspeaker systems. Keep up the great work on a really interesting magazine and some great amplifier and loudspeaker designs.

Ranald Grant,
Bellbowrie, Qld.

lems. Maybe half of us can expect some delivery surprises and the other half can expect delivery disappointments.

About seven years ago I bought a block of vacant rural/residential land that only had a block number, not a street number. I applied for and was duly supplied with a street number. This arrived before I built my house. If you try to navigate to my place on SatNav with the street number you will be directed to the opposite side of the street several hundred metres away, but using the block number provides the correct result.

So it seems to me that there is a disconnect between the map makers/suppliers and the SatNav map users. As well as the inaccuracies in the maps on SatNavs and phones etc, they are also out of date.

The situation affects me in other ways. I recently had an ADSL problem and while talking to Telstra about it, I was asked for my address. I gave the street address, only to be told that no such address existed, so other businesses use the same out-of-date mapping technology. I told them that I had been receiving and paying bills mailed to that address for five years. After a short silence the discussion continued. I now get Telstra bills by email.

If you are planning a drone delivery any time soon, good luck.

Peter Chalmers,
Clear Mountain, Qld.

The joys of programming PIC32 processors

I am writing with regard to Hamish Rouse's letter in Mailbag (SILICON CHIP, December 2015, Page 4). In 2012, Imagination Technologies bought MIPS Technologies, and they licensed the use of the MIPS architecture to Microchip. The MIPS architecture is explained in detail in their website (see **https://imgtec.com/mips/architectures/**). I think that in order to make sense of the PIC32 processors it is best to get a good grasp of the MIPS architecture first, then go back to the PIC documents.

I am also a lover of assembler level coding and for the last 45 years I have written code for many processors, for both work and play. Over those years, the learning curve for new processors has become steeper and steeper, with more complex instruction sets and greater integration of peripherals into the die. The main driver for this is to make the machine instructions more compatible with higher level languages such as C.

One example of this trend is implementation of the Java Virtual Machine in hardware. The result is a plethora of instructions at the machine level to implement variants of a real world problem (I have lost count of the number of ways to multiply in MIPS architecture – signed/unsigned, 8/16/32 bit, fixed or floating, SIMD, with or without accumulating the result).

Then there are the complexities of housekeeping in these architectures – such as pipelined instructions where the result is not available immediately, large numbers of hardware registers to shuffle, tasks offloaded to coprocessors. These are easily managed in an optimising compiler but not manually. The role of assembler is relegated to carefully-crafted code snippets for device drivers and the like.

Assembler is a bit like Sudoku; great exercise for the mind but not very productive. Real world problems are usually too complex to solve effectively in assembler. A high-level language program is quicker to write, easier to debug, more portable and easier to maintain. With the compilers and processors today, the end result is often only a few percent slower than the best that can be achieved using assembler.

In areas like DSP applications, it is a brave person who writes their own. PhDs are awarded to such people if they succeed. It is far easier to search the literature and use what someone else has done. Usually, there will be a library module to do the job or code snippets in articles; no need to understand how they work, just design tests to ensure they do.

I am not saying assembler is dead. Hamish makes the point that understanding assembler gives a better insight into what high level languages actually do. I taught a COBOL course many years ago and one exercise I gave was a program that examined itself and printed out the assembler code.

Many students spent hours changing the code to see what the compiler would do and most agreed that it was worthwhile. Good luck with the MIPS architecture; it's a beast.

Alan Cashin,
Islington, NSW.

Many TV sets will need a DVR or set-top box

Now that the Nine network has broken ranks with MPEG4 it would appear that many TV owners will not be able to receive some of Channel Nine's existing and new outlets. We have two sets, one is five year and the other is six years old. No MPEG4. So we have to either use the PVR or get a set-top box.

Barrie Smith,
Cromer, NSW.

DAB+ antenna works well

Firstly, I would like to say that the DAB+ antenna project was not only timely but very welcome. I recently lost my venerable old AM/FM radio in my shed workshop; it fell off its perch and landed heavily on the concrete floor, to be silent forever. I decided to replace it with a digital radio. Of course, when I tried to scan the stations there were none, due in no small part to steel walls all around and a metal roof.

Disappointed, I decided that I should look at using some online calculators and design an external antenna for myself. Then lo and behold, the November issue of Silicon Chip arrived in the post box and what was on the front cover – a DAB+ antenna, saving me the time and effort of designing my own.

Needless to say, I wasted no time in gathering the materials to build one – two actually; one for the workshop and one for the house. I installed the shed antenna on the weekend and what a difference! I was able to scan stations that I had not seen before and each one showed a signal strength of 100%.

So, may I say thanks for a great and timely project. Along with Cliff King in the October Silicon Chip Mailbag, may I also add my voice to request a digital TV antenna project to complete the trifecta.

On different note, I notice that the Nine Network has made its channel 90 high definition, from 26th November. This can only be a good thing but do you have any idea if the other networks are going to follow suit?

With 4K TV on the way in the future, it cannot come soon enough. Now all we need is something worth watching on TV.

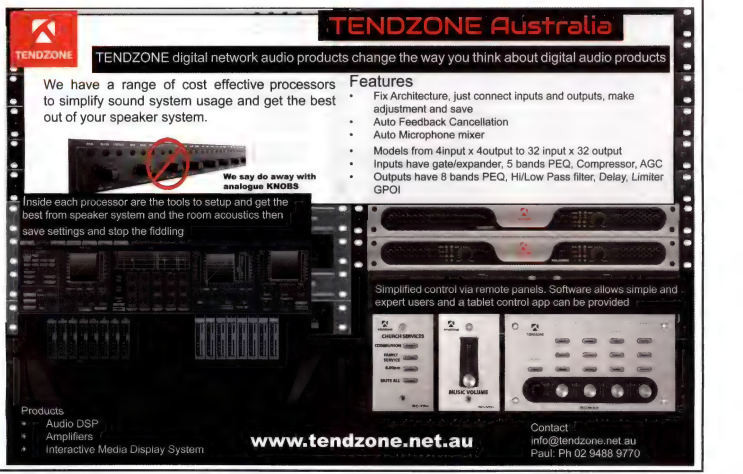
Peter Clarke,
Woodcroft, SA.

SMD merits & drawbacks

I've recently started using SMD resistors in my projects and I agree with all the benefits that have been mentioned in previous readers' letters. However, one of the biggest advantages to me, that hasn't been mentioned, is not having to drill holes, which saves so much time.

Plus, the time taken to learn the knack of soldering the chip onto the PCB is negligible. Learning the different sizes of resistors is also another skill to cope with. If I can do it, it can't be that difficult!

Robert Fields,
Dunedin, Otago, NZ. SC



BLOOD PULS

What they do & how they work

Ever visited someone in hospital and noticed a small sensor clipped over one of their fingers? That's actually the 'business end' of a blood pulse oximeter, used to monitor the oxygen level in a patient's blood – an indication of how well their lungs and heart are working. Now that fully self-contained pulse oximeters are available on ebay for around $15 (including postage!), you can easily buy one for your personal use. Here's a quick run-down on exactly what they do and how they work.

EVEN BEFORE WE PRESENTED our new Arduino-based USB Electrocardiogram in the October 2015 issue of SILICON CHIP, we received a number of enquiries from readers regarding blood pulse oximeters.

One reader even suggested that we might be able to describe one of these as a project in the magazine, as well.

But let's start by looking at what blood pulse oximeters actually do and how they work.

When we breathe in, our lungs allow oxygen from the air to pass into our bloodstream.

Most of the oxygen molecules become attached to haemoglobin, a protein located inside red blood cells. The blood in your arteries then carries the oxygenated haemoglobin around your body, so the oxygen can be transferred into the various tissues to provide them with 'fuel'. The de-oxygenated blood then returns to the heart and lungs via your veins.

So the main job of our lungs is to transfer oxygen from the air we breath into our blood and then the blood carries the oxygen to all of the tissues that need it. Anything that interferes with these functions – like a problem with our lungs or narrowing and/or blockages in our arterial blood vessels – will have a significant effect on our overall health and well-being.

This was realised by physicians many decades ago and various diagnostic procedures were developed to allow the health of our respiratory and circulatory systems to be assessed. Unfortunately many of these procedures were intrusive and/or painful.

Then it was discovered in the 1930s that the oxygen level in arterial blood could be measured painlessly and non-intrusively using light at different wavelengths, either reflected from or passing through human tissue.

By JIM ROWE

The first "optical oximeter" is credited to G.A.Millikan in 1942, while in 1964 the first "absolute reading" ear oximeter was made by Shaw. It made use of eight different wavelengths of light and was commercialised by Hewlett-Packard.

However because of its size and cost, it came to be used mainly in operating theatres and sleep laboratories.

The pulse oximeter was developed in 1972 by bioengineers Takuo Aoyagi and Michio Kishi, at Nihon Kohden in Japan.

This was in many ways the real breakthrough, using only two wavelengths of light (red and infrared or 'IR') but taking advantage of the differing absorption of these two wavelengths when passing through human tissue during the pulsing of arterial blood as a result of the heart's pumping cycle.

Since then, pulse oximeters have developed dramatically, shrinking in physical size to reach their current size of around 65 x 36 x 33mm – much the same size as a 'clip on a fingertip' sensor probe used with one of the earlier oximeters.

The price has also fallen dramatically, to a point where they can now be bought on the internet for less than

E OXIMETERS

$A10, plus a few dollars for postage.

What they do

There are two basic principles involved in the operation of a blood pulse oximeter. One is that the oxygenated haemoglobin (HbO_2) in arterial 'red' blood and the de-oxygenated haemoglobin (Hb) in venous 'red-blue' blood differ quite markedly in terms of the way they absorb or pass light - in particular, at the wavelengths of red light (around 660 nanometres) and IR light (around 915nm).

This is shown by the graph of Fig.1, which shows the degree to which light at various wavelengths is absorbed by the HbO_2 in arterial blood (red curve), compared with that absorbed by Hb in venous blood (blue curve).

As you can see, arterial blood with its higher level of HbO_2 absorbs very little red light, but somewhat more IR light. On the other hand, venous blood with its higher level of de-oxygenated Hb absorbs somewhat more red light, but less IR light.

Next consider what happens if we pass light of these two different wavelengths through human tissue which normally has a good blood circulation – like that in a human fingertip. This is what happens in an oximeter, as shown in Fig.2.

As you can see, two LEDs just above the fingertip are used to provide the

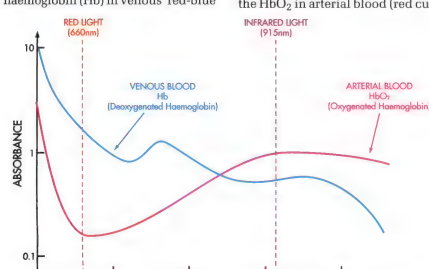


Fig.1: Oxygenated arterial blood absorbs more IR light, while de-oxygenated venous blood absorbs more red light.

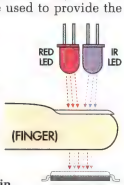


Fig.2: Taking advantage of the behaviour illustrated at left, blood pulse oximeters use this simple measuring setup to measure the ratio of red and IR light passing through a fingertip.

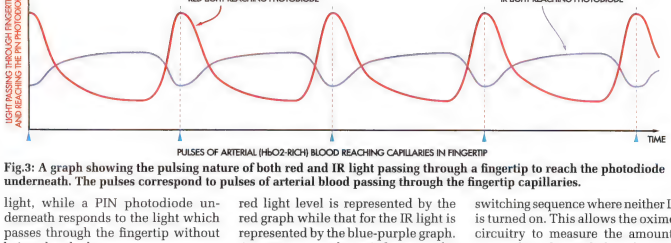


Fig.3: A graph showing the pulsing nature of both red and IR light passing through a fingertip to reach the photodiode underneath. The pulses correspond to pulses of arterial blood passing through the fingertip capillaries.

light, while a PIN photodiode underneath responds to the light which passes through the fingertip without being absorbed.

Now we come to the second principle involved in the pulse oximeter's operation and the reason why they're called "pulse" oximeters. This can be understood as follows.

After a pulse of oxygen-carrying blood has been pumped out by the heart's left ventricle and circulated via the arteries, the oxygen is rapidly transferred out into the tissues via the tiny capillaries linking the arterial and venous blood vessels. As a result, inside a region like a fingertip (or an ear lobe), the level of HbO_2 in the capillaries has dropped significantly, while the level of de-oxygenated Hb in them has risen to a relatively high level.

This means that overall and as shown in Fig.1, the capillaries and tissues in the fingertip absorb a relatively high proportion of the red light but a somewhat smaller proportion of IR light. In other words, the ratio of red light to IR light passing through the fingertip to reach the PIN photodiode is relatively low.

But as soon as the next pulse of arterial blood arrives from the heart, with its higher level of HbO_2, this situation changes markedly. Now and for a brief time the capillaries have a considerably higher level of HbO_2 and as a result, the absorption of red light drops significantly, while that of the IR light rises.

So the ratio of red light to IR light reaching the PIN photodiode swings high – at least until the oxygen passes out into the tissues.

The end result is that the levels of red and IR light passing through the fingertip swing up and down cyclically in time with the 'heartbeat' pulses of arterial blood reaching it. This is shown in Fig.3, where the transmitted red light level is represented by the red graph while that for the IR light is represented by the blue-purple graph. As you can see, the ratio between the two swings back and forth in time with the pulses of HbO_2-rich blood reaching the fingertip capillaries.

In essence, it's the peaks in the red/IR light ratio which are the main indicator of the person's 'circulatory health', because they're an indicator of the degree of HbO_2 'saturation' in their arterial blood.

So it's the job of the pulse oximeter as a whole to measure the amplitude of these peaks in the red/IR light ratio, and work out the corresponding 'saturation pulse oxygenation level' (usually shortened to SpO_2).

How they work

At this stage you're probably wondering how, if the oximeter uses the simple sensing set-up shown in Fig.2, it can work out the ratio of red light to IR light reaching the single PIN photodiode under the fingertip.

The answer to this is quite straightforward: it does so by switching the red and IR LEDs on and off in sequence, so they're never on at the same time. This allows the transmitted light at each wavelength to be measured separately.

In fact there's also a step in the switching sequence where neither LED is turned on. This allows the oximeter circuitry to measure the amount of external 'ambient' light which may be able to reach the PIN photodiode (around or through the fingertip), allowing it to be subtracted from the transmitted red and IR light levels to get a more accurate reading of both.

So the oximeter is repeatedly switching through a 'red LED only/IR LED only/neither' sampling sequence, at a rate of about 50 times per second. This speed is high enough to ensure that the red/IR ratio peaks can be captured faithfully, as a normal human heart pulse rate varies between about once and twice per second (60 – 120 bpm but much higher rates can be sustained during heavy exercise).

From this you won't be surprised to hear that there's a microcontroller at the heart of virtually all pulse oximeters. The basic configuration is shown in Fig.4, and the micro controls the LED switching sequence, measures the output from the PIN photodiode via a current-to-voltage converter and its internal ADC (analog to digital converter), crunches this data to work out the SpO level, and displays the result on a small LCD readout.

With most of the latest pulse oximeters the micro also measures the time between arterial blood pulses and displays the corresponding heart beat rate in beats per minute. It often displays the varying red/IR light ratio as a 'bouncing bar chart' as well.

You can see from Fig.4 that there's not a lot inside a modern pulse oximeter. Which explains how, thanks to surface-mount technology, it can all be squeezed (along with a couple of AAA cells) into a tiny fingertip enclosing probe like the ones shown in the photos. It also explains how the latest devices can be sold for such a low price.

So that's what blood pulse oximeters

Inside a ContecOximeter – there's not much to it and similar oximeters are available online for less than $15.00!

What is a "normal" blood oxygen level?

In order to function properly, you body needs a certain amount of oxygen in the bloodstream. When the level falls below a certain amount, "hypoxia" (or hypoxemia) occurs. But what is this amount?

Blood oxygen levels vary slightly from person to person; however in a healthy person, a level of between 95 and 100% is considered normal – in other words, at least 95% of the body's ability to transport oxygen via the bloodstream is happening. (In truth, 100% can never really be achieved – 99% is about the maximum).

Between 90 and 95%, a conscious person may experience a "shortness of breath". Below 90% is cause for concern and, indeed, may require administration of pure oxygen to make up the shortfall.

Hypoxia has a number of causes, mostly to do with illness or disease (especially of the lungs). Another reason is drowning or near-drowning, where first-aid (CPR) has brought a person back from near death. Pure oxygen is always administered once breathing has been re-established, because hypoxia is almost certainly present (the depth depending on length of immersion).

One cause getting increasing attention these days is sleep apnoea, where the person effectively "forgets" to breathe for a period during sleep, lasting from a few seconds to a few minutes. This results in no fresh oxygen getting into the lungs and, therefore, into the bloodstream. Blood oxygen levels drop quite quickly – in a medical situation this would almost certainly set off a patient alarm so appropriate attention can be given.

While the body should have an "automatic" response to severe sleep apnoea, waking the person, before this occurs hypoxia will occur at some level, along with hypercapnia, an *excess* of CO_2 in the bloodstream.

In sleep apnoea, saturation HbO_2 levels of 85-90% are relatively common, while levels below 80% are considered severe/extreme. Prolonged levels below 80% risk organ and tissue damage, including irreversible brain damage and in the worst cases, death.

do and how they do it. Now for the question that seems to have occurred to at least a few of the SILICON CHIP readers:

Why not do an oximeter project, perhaps as an add-on to the ECG project in the October 2015 issue?

Since there's apparently so little inside a pulse oximeter, as shown in Fig.4, this is a fair question. In fact, we recently built a prototype Arduino-based oximeter, designed to hook up to a PC via a USB cable (like the ECG project). But there were significant problems:

1. Although the SpO_2 level can be worked out from the transmitted peak red light/IR light ratio, the relationship between them isn't a linear one. Because of this the micro in commercial pulse oximeters uses a 'lookup table' to find the SpO_2 level corresponding to the peak red/IR ratio – and the data stored in the lookup table must be prepared by testing a reasonable number of human subjects. This is fine if you're building a mass-produced commercial oximeter, but it isn't really feasible when it comes to a 'one off' DIY project.

2. While the hardware, firmware and software side of the project's electronics was fairly straightforward, the physical side of the fingertip sensor was tricky – involving a couple of small PCBs in this part alone, linked by ribbon cable and mounted inside the two parts of the smallest 'jiffy box' enclosure fitted with a small hinge and lined with adhesive black felt. This sensor assembly by itself was larger than one of the low cost commercial oximeters and not as effective or attractive. And yes we also looked at the possibility of using a cheap oximeter as the head-end, and interfacing its signals to an Arduino. Trouble is, these units are not necessarily based on a standard micro and even if we settled on one particular unit, there would be no guarantee of continuing supply.

So that is where it stands for the moment. In the meantime, if you'd like your own pulse oximeter you are best advised to buy one of the surprisingly low-cost units available via the internet.

Want to try some smartphone apps out? See our list of heart rate monitors overleaf:

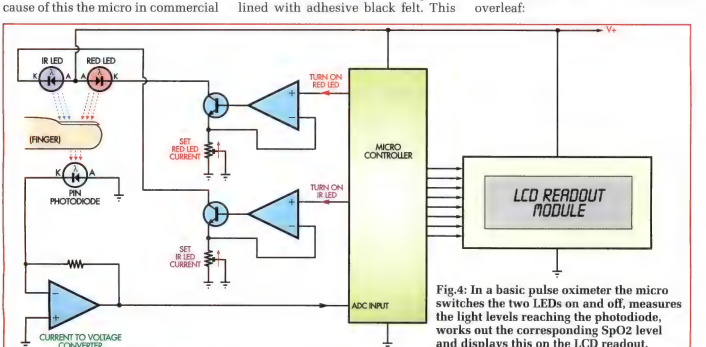


Fig.4: In a basic pulse oximeter the micro switches the two LEDs on and off, measures the light levels reaching the photodiode, works out the corresponding SpO2 level and displays this on the LCD readout.

Heart monitoring apps for smartphones

Runtastic Heart Rate Monitor is available for both Android and iOS smartphones and not only measures heartbeat but stores and graphs a great deal of heart-related data as well. There's a simple free version and a paid version.

If you have a reasonably modern smartphone, there are quite a large number of apps which use the camera in your phone to read heart rate (in some cases, among other things).

Note that none of these apps can measure blood oxygen levels but knowing your heart rate while resting, during mild activity and during intense activity is essential information, something your medico would find really helpful.

In fact, if your health care professional suspects any of a variety of cardio-related problems, he or she is *likely* to send you off for a "Stress ECG" test.

While this looks at a lot more than heartbeat (eg, it also graphs your heart activity), the fundamental tests of resting, mild activity and intense (or stressful!) activity form the basis of a Stress ECG test.

How do these apps work?

Most work in one of two ways (and in some cases both ways) – they usually use the smartphone's inbuilt white LED flash and camera to examine the blood flow (usually in your finger, just like the pulse oximeter) and compute the differences between pulses.

In some (fewer) cases, they simply use the phone's inbuilt camera to focus on a face and look at the almost invisible movement in facial features with each pulse of the blood vessels.

Some phone apps offer both types, so you can look at your own heartrate or someone elses!

Because there is only one light source in the flash/camera method, the app is not capable of determining venous or arterial blood flow so cannot determine oxygen levels. Similarly, in the facial recognition method, this is not possible.

There are some drawback in using the apps: most of the flash/camera tests require intimate contact with both flash and lens, without movement.

While this is not particularly difficult, it does run the risk of oiling or smudging the camera lens. And the facial recognition app requires the subject (and camera!) to stay perfectly still and in focus for a time. But apart from those, we didn't have too much trouble.

There are also some apps which use the phone's inbuilt microphone to actually listen for the heartbeat.

Where from, how much:

Some of the apps listed below are free, others have a small charge (the highest we found was $US1.99). The old adage that you get what you pay for really doesn't apply here because some of the best features are in the free apps!

We're not going to go out on a limb and recommend any particular app – do your own research and decide which one is right for you. First stop could be the iTunes/App Store or Google Play (of course, it also depends on which type of smartphone you have!

In no particular order, here are some to look at (there are many more – Dr Google is your friend . . .)

Runtastic Heart Rate Monitor (iOS and Android) www.runtastic.com

Pulse Phone (iOS) www.antimodular.com

Instant Heart Rate (Android, iOS and Windows) Free. instantheartrate.com

ADT Pulse (iOS) Free (Says Android but URL not found) www.adt.com

MotionX 247 (iOS) – sleep tracker AND heart rate monitor http://24-7.motionx.com/

Heart Rate (iOS) – Also has facial recognition to measure heartbeat www.azumio.com

Cardioo (iOS) ditto heart rate but not designed to measure from finger www.cardiio.com

And if you're really keen . . . check out www.iphoneness.com/iphone-apps/best-heart-rate-monitors-for-iphone/ for 23 of the top heart rate monitors for iPhone. There are similar sites for Android smartphones. SC

Instant Heart Rate is a simple free app for Android, iOS and Windows and can link to other health applications from the same company.

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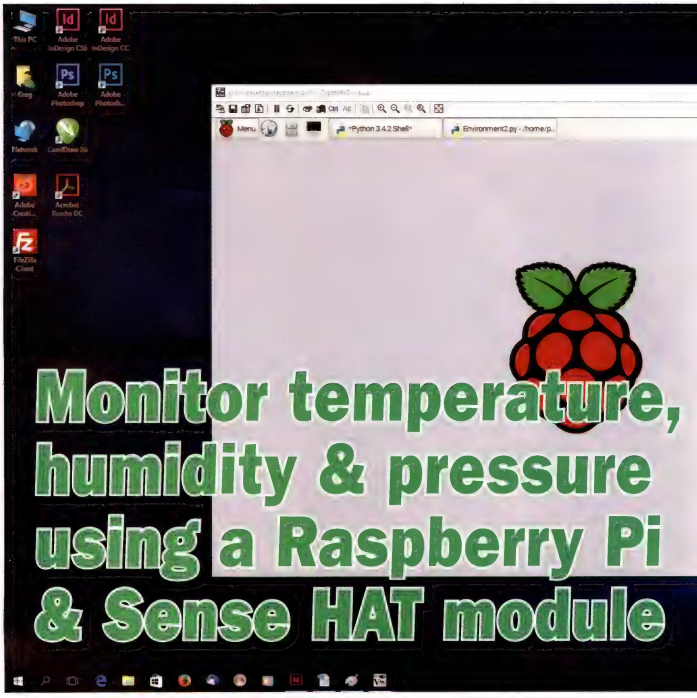
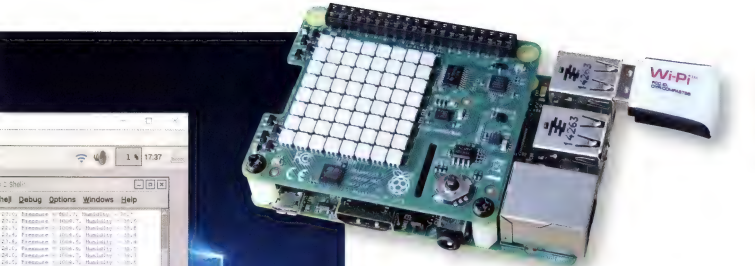


Want to be able to monitor temperature, humidity and pressure using a web browser from a remote location? Here's how to do it using a Raspberry Pi 2 Model B computer, a plug-in Sense HAT module, a Wi-Pi WiFi dongle and an 8GB microSD card.

WHAT'S A Raspberry Pi? If you've been sleeping and missed all the hype, then no, it's not something that four and twenty blackbirds are baked in. Instead, it's a $40 credit-card-size single-board computer boasting a 900MHz quad-core ARM Cortex-A7 CPU, a VideoCore IV multimedia coprocessor, 1GB of on-board RAM, a micro-SD card slot and a full HDMI port to output video and sound to a monitor or TV.

Also on-board are four USB ports, an Ethernet port, a 40-pin GPIO (general-purpose input/output) port, a camera interface, a display interface and a combined 3.5mm audio & composite video jack. It's powered from a 5V plugpack and runs a cut-down Linux operating system such as Raspbian, RaspBMC, Arch Linux or OpenELEC.

We're using the Raspberry Pi here with a Sense HAT



This view shows the Raspberry Pi with the Sense HAT module plugged into its GPIO port & a Wi-Pi dongle connected to one of its USB ports.

multi-sensor module to form a basic temperature, humidity and pressure monitor. There's no soldering involved – it's just a matter of plugging everything together and bashing a keyboard for an hour or so to set it up.

We're going to start by showing you how to get your own Raspberry Pi running by installing (and configuring) the Raspbian operating system. We're then going to describe how to connect it to your WiFi network before moving on to retrieving the various readings from the Sense HAT module using some simple Python scripting programs.

We're also going to show you how you can run the Raspberry Pi "headless"; ie, no keyboard, mouse or monitor. That's done by using an application called TightVNC. This lets you display your Raspberry Pi's desktop on another computer (eg, a Windows PC), so that it can be controlled using the remote PC's keyboard and mouse.

That's all described below in Pt.1 this month. We'll follow on next month by showing you how to stream the Sense HAT sensor readings to a web server, so that you can access them using a browser over the internet. That's done by installing Apache Web Server and copying across the necessary software program which we'll make available on our website.

Sense HAT module & Wi-Pi

As mentioned, a Raspberry Pi Sense HAT module is one of the major components in this project. It plugs directly into the Raspberry Pi's 40-pin GPIO port and carries an impressive array of on-board goodies. These include:

- A temperature and humidity sensor;
- An air-pressure sensor;
- An accelerometer, gyroscope and magnetometer;
- An 8x8 LED matrix display; and
- A miniature joystick

We'll just be using the temperature, humidity and air-pressure sensors here but there's nothing to stop you from experimenting with the remaining sensors, as detailed on various internet sites (Google is your friend).

The other major part used in our system is a Wi-Pi WiFi dongle. This $10 part connects to one of the Raspberry Pi's USB ports and frees the unit from a wired network connection. It works straight out of the box (more on this later). The Edimax EW-7811Un WiFi dongle is also compatible with the Raspberry Pi and there are others, as a Google search will reveal.

Note, however, that many WiFi dongles are not directly supported by Raspbian although it may be possible to get them going by downloading and installing suitable drivers. However, that can be an exercise in frustration unless you're a real Linux expert. In addition, many dongles draw more USB power than can be supplied by the Raspberry Pi and so would need to be run via a powered USB hub.

For minimum hassle, we suggest you stick to either the Wi-Pi or the Edimax EW-7811Un (see parts list pan-

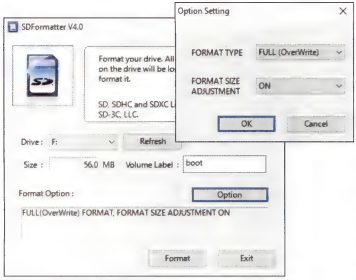


Fig.1: if necessary, the microSD card can be formatted using the freeware SDFormatter utility. Set the Format Type & Format Size Adjustment options as shown.

el). Alternatively, you can dispense with WiFi set-up if a wired network connection is convenient.

What else is needed?

As well as the above parts, you'll also need a 5V 1A plugpack fitted with a micro-USB connector to power the system and an 8GB (up to 32GB) microSD card.

If you've owned an Android smartphone, then you probably already have a suitable plugpack with a 5V USB output lying around. You may even have the correct USB to micro-USB cable; if not, you can pick one up for a few dollars.

The microSD card functions as the Raspberry Pi's boot disk. It holds the Raspbian operating system and should preferably be a class 10 type, although a class 6 card will do the job.

You'll also initially need these parts to set up the unit: a USB keyboard and mouse (wireless units are OK), an *HDMI* cable, a monitor and a USB memory card reader. If you don't have a spare keyboard, mouse or monitor, you can temporarily borrow them from your main PC for the setting-up procedure.

Once the set-up has been completed, the unit can be run "headless"; ie, without the keyboard, mouse and monitor. The card reader is required only to install the operating system to the microSD card.

OK, here's how to install Raspbian and set up the system for temperature measuremerts:

Step 1: Install Raspbian

Once you have all the parts, the first step is to install the Raspbian OS on the microSD card. It's just a matter of pointing your PC's web browser to the Raspberry Pi Foundation's website at **https://www.raspberrypi.org/downloads** and following the instructions.

If you intend pressing a pre-used microSD card into service, then it's a good idea to format it first. Begin by downloading the SD Card Formatter utility (from **https://www.sdcard.org/downloads/formatter_4/**), then unzip the file and install it on your PC. You then launch the utility and format the microSD card (to FAT32) using the Full Overwrite option and with the Format Size Adjustment option set to ON (Fig.1) – see **https://www.raspberrypi.org/documentation/installation/noobs.md**

On the other hand, if you have a new microSD card, this will come pre-formatted, so you can skip the formatting procedure.

As indicated on the website, there are two ways to go about installing the Raspbian OS: (1) using the zipped image file; or (2) using NOOBS.

If you elect to use method 1, begin by downloading the zipped Raspbian image file to your PC (Raspbian Jessie is the latest version as this is being written). This is a 1.3GB zip file, so it will take an hour or so to download with an ADSL2 or cable connection. Once the download is complete, unzip the file to recover the 4.3GB image file.

The next step is to write the Raspbian OS to the micro-SD card using an image writing tool – see **https://www.raspberrypi.org/documentation/installation/installing-images/README.md** This website has instructions for PC, Mac and Linux operating systems.

If you're using a Windows PC, you will have to download and install the Win32 Disk Image utility (available from **http://sourceforge.net/projects/win32diskimager/**). You then simply launch the utility, select the unzipped image file, choose the drive to write the image to and click the write button (see Fig.2); the utility then does the rest. Be sure to chose the correct drive to write the image to, otherwise you could lose valuable data.

By contrast, both Mac and Linux systems use the in-built "dd" command line utility. Just follow the instructions on the website.

Step 2: The NOOBS alternative

Method 2 involves first downloading NOOBS (New Out Of the Box Software), also found at **https://www.raspberrypi.org/downloads/** This is a 983MB download and again comes down as a zip file. You then simply copy the unzipped files to the micro-SD card (no image file writer is need), as described in the included readme file.

NOOBS is basically an easy operating system installer. Its advantage is that it makes it easy to install alternative operating systems the first time it's started. Only Raspbian is included in NOOBS though; the others are downloaded and installed from the internet.

Step 3: Fire up the RPi

Now to get Raspbian running on the Pi. Plug in your keyboard, mouse and monitor cables but leave the Sense HAT and the Wi-Pi dongle to one side for the time being. That done, insert the microSD card in the Pi's card reader, turn on the monitor and plug the USB power cable into the micro-USB connector.

The Raspberry Pi will begin to boot as soon as power

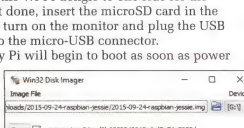
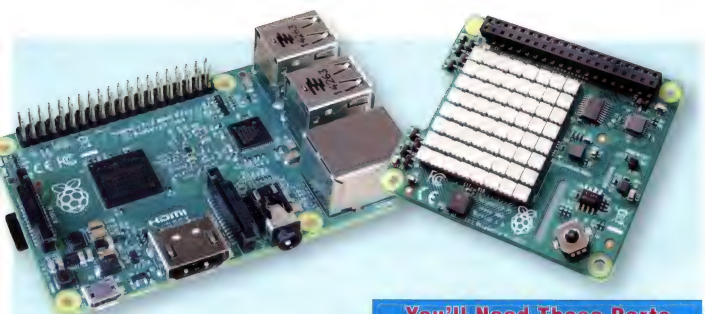


Fig.2: use Win32 Disk Imager to write the Raspbian image file to the microSD card (Windows PCs only).



The Sense HAT module (right) plugs directly into the Raspberry Pi 2 Model B computer's 40-pin GPIO port.

is applied. If you've written an image file to the micro-SD card, Raspbian should boot straight to the graphical user interface (GUI). Alternatively, if you've used NOOBS, a window will appear prompting you to install the operating system – just tick the box next to Raspbian and click the Install button. The system should then boot to the GUI.

If it doesn't, just type **startx** to launch the GUI. The default username is **pi**, while the default password is **raspberry** (although by default, it should not prompt you for these).

Step 4: Configure it

The next step is to configure the system for your location, timezone and keyboard. In particular, the default keyboard configuration is for the UK and it can give the wrong characters in some cases; eg, an "@" character when double quotes are entered.

Begin by clicking **Menu -> Preferences -> Raspberry Pi Configuration**, then click the Localisation tab on the resulting dialog box. You can then Set your Locale (leave the Character Set at UTF-8) and the Timezone. Ignore the Set Keyboard button; there's a bug in this configuration utility and the keyboard setting doesn't stick when you reboot. Fortunately, there's an easy way around this and we'll get straight to it.

Having set the locale and the timezone, click the OK button and allow the system to reboot. Now for the keyboard configuration.

Launch the Terminal (click on the taskbar icon at top left), then enter the command

```
sudo raspi-config
```

to launch the Software Configuration Tool. That done, select Internationalisation Options (they've got to be kidding!), then select Change Keyboard Layout.

Next, select your keyboard type [eg, Generic 105-key (Intl) PC], then select "Other" from the following dialog. You then choose English (US), then use the Up arrow key to scroll up to the English (US) option (again). Note that there must be no qualifying text after the English (US) listing.

Next, tab to **OK** and then repeatedly press the Enter key to take you back to the opening menu of the Soft-

You'll Need These Parts

Core parts

1 Raspberry Pi 2 Model B computer module . . . *$48 from element14*

1 Raspberry Pi Sense HAT module . . . *$47.98 from element 14*

1 Wi-Pi WiFi dongle . . . *$9.31 from element14* (see text)

1 8-32GB micro-SD card (class 6 or class 10) . . . or purchase a pre-programmed micro-SD card from element14 or Wiltronics

1 5V 1A power supply with USB to micro-USB cable

The parts required during set-up

1 USB keyboard and mouse (wireless units should work, provided they're paired)

1 monitor with HDMI or DVI input

1 HDMI-HDMI or HDMI-DVI cable to suit monitor

1 microSD card reader

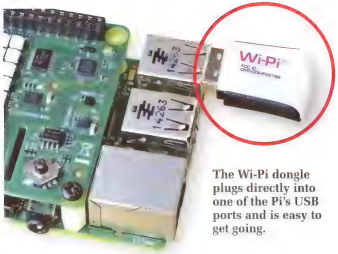
Raspberry Pi starter packs

If you don't have any of the core parts, Wiltronics has a number of Raspberry Pi starter packs – see **www.wiltronics.com.au** These include:

(1) A ***Basic Starter Pack*** consisting of a Raspberry Pi 2 Model B computer, a 5V power supply adaptor, a case and a pre-programmed (NOOBS) 8GB microSD card.

(2) A ***Standard Starter Pack*** which includes the Basic Starter Pack parts and adds a 2-metre HDMI cable and a 3-metre Ethernet cable.

(3) A ***Raspberry Pi 2 Model B WiFi Pack*** which includes the Basic Starter Pack parts plus a USB WiFi module (with whip antenna), a card reader and a 2-metre HDMI cable.



The Wi-Pi dongle plugs directly into one of the Pi's USB ports and is easy to get going.

ware Configuration Tool. Finally, use the tab key to select **Finish**, press **Enter** and that's it – your keyboard is now configured.

You can test this by opening the Leafpad text editor (**Menu -> Accessories -> Text Editor**) and typing the double quotes (") symbol. If you get double quotes rather than an @ symbol, then all is well.

Step 5: Change the password

As stated, the default username is "pi" and the default password is "raspberry". You can keep the "pi" username but leaving the default password is never a good idea so the next step is to change it.

That's also done using the Software Configuration Tool. Just enter the command **sudo raspi-config** in the Terminal, choose Change User Password and follow the bouncing ball (well, not literally).

Be sure to use a strong password and write it down in case you forget it.

The Software Configuration Tool also allows you to choose various boot options. You can elect to boot straight to the Desktop GUI with automatic login (the default), to a Text console requiring a username and password, or to two other variations of these.

Step 6: Get the WiFi going

Getting the WiFi going is easy. First, shut down Raspbian, connect a Wi-Pi (or other compatible) WiFi dongle to a spare USB port and reboot **(note: it's necessary to boot the system with the Wi-Pi dongle connected. It won't work if you connect it to a USB port after the system has started).**

During the boot process, the system automatically detects the Wi-Pi and installs the correct driver. Wait until the desktop GUI appears, then hover the mouse over the network icon on the taskbar at top right. A message will appear telling you that wlan0 is "Not associated".

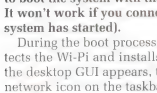


Fig.3: connect to your WiFi network by selecting it and entering the password.

Now click the network icon; it should be scanning for local APs (WiFi access points). Give it time to discover any local WiFi networks, then select your WiFi network from the list, enter your WiFi password in the resulting dialog box and click OK. The Wi-Pi will then connect to your WiFi network and the networking icon on the taskbar will be replaced with the WiFi icon.

That's it; your WiFi connection will now be working. You can check this by launching the web browser (it's the icon next to the Menu button) and entering in a web address. You will need to enter in the full **http://www** string in order to go direct to a website. If you just start with the address **www**, it will (annoyingly) search for the entry using the DuckDuckGo search engine.

As an aside, when your WiFi password is entered as described above, the system places an entry for your network in the **/etc/wpa_supplicant/wpa_supplicant.conf** configuration file. The associated **/etc/network/interfaces** file is left completely unmodified by this process.

If you have a second WiFi network that you connect to, its entry will also be placed into **wpa_supplicant.conf** (beneath the first entry) when you go through the above procedure – see Fig.4.

Don't get sucked into hand-fettling either of the above two configuration files as described in numerous online sites. Provided your WiFi network broadcasts its ssid (ie, network name), that's not necessary under normal circumstances.

With the WiFi working, it's time for some updates and upgrades (these will take quite some time):

```
sudo apt-get update
sudo apt-get upgrade
sudo reboot
```

Step 7: The hidden WiFi fix

What if your WiFi ssid is hidden by the router? That's a somewhat different kettle of fish.

In that case, you do have to manually edit the **wpa_supplicant.conf** file and that's best done using Raspbian's Leafpad text editor (yes, you can use the Nano terminal editor but a GUI text editor is easier for anyone new to Linux). There's just one precaution – you have to open Leafpad as a super user. Here's what to do:

(1) Click **Menu -> Run** and in the resulting dialog enter the command **sudo leafpad**

(2) In Leafpad, click **File -> Open -> File System**, then navigate to the **/etc/wpa_supplicant** folder and open **wpa_supplicant.conf**

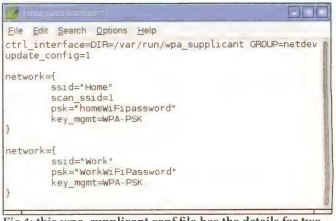


Fig.4: this wpa_supplicant.conf file has the details for two WiFi networks. Note that the scan_ssid=1 line must be manually added for a hidden network.

(3) There will already be two lines in this file. All you have to do is add the following lines, substituting your WiFi's network name and password as appropriate (keep the double quotes and note the opening and closing parentheses):

```
network={
      ssid="YourWiFiNetworkName"
      scan_ssid=1
      psk="YourWiFiPassword"
      key-mgmt=WPA-PSK
}
```

Save this file, then reboot the system; it should now connect to your hidden WiFi network.

Fig.4 shows an example **wpa_supplicant.conf** file. In this case, two WiFi networks are present (one for home and one for work). Note the **scan_ssid=1** entry in the first network; this line is necessary only if the WiFi network is hidden and should immediately follow the **ssid= "YourWiFiNetworkName"** line.

By the way, there's a quick way of configuring **wpa_supplicant.conf** if you have a hidden network. Start by clicking on the networking icon on the taskbar, then select any one of the detected WiFi networks and enter a false password into the resulting dialog. It's then just a matter of opening **wpa_supplicant.conf** (sudo leafpad), editing the network name and password and inserting

```
scan_ssid=1
```

directly under **ssid="YourWiFiNetworkName"**.

Alternatively, you could temporarily un-hide your WiFi's SSID (via your router's web interface), connect it to the network as described above, and then hide it again. It would then just be a matter of inserting the **scan_ssid** line in **wpa_supplicant.conf** and rebooting.

Once it's working, update and upgrade the system as described at the end of the previous section.

Step 8: Connect the Sense HAT

With the WiFi now working, it's time to connect the Sense HAT. Before plugging it in, connect a couple of M3 x 12mm Nylon spacers to the mounting holes on the opposite side of the header. This step is necessary to ensure that the otherwise unsupported edge of the module cannot be pushed down onto the Pi's HDMI socket.

Note that it will be necessary to enlarge the mounting holes to 3mm before attaching the spacers (the module comes with 2.5mm mounting holes). Do this carefully with a low-speed drill, to avoid damage to adjacent tracks and parts on the Sense HAT.

Once the spacers are in place, power down the Raspberry Pi, plug the Sense HAT module into the GPIO port and reboot. The Sense HAT software is then installed from the Terminal, as follows:

```
sudo apt-get install sense-hat
sudo pip-3.2 install pillow
sudo reboot
```

It's now time to check that the Sense HAT is working and will respond to a simple program entered into

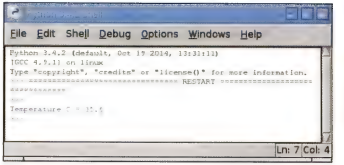


Fig.5: this is the output that appears in Python when running the simple temperature reading program at the bottom of this column.

Python 3, a high-level scripting language that comes with Raspbian.

Start by opening Python 3 as sudo from a terminal window by entering the command:

```
sudo idle3 &
```

Wait until the Python 3 Shell dialog opens, then open a new window by clicking **File -> New File** and enter in the following code:

```
from sense_hat import SenseHat
sense = SenseHat()
sense.show_message("It Works!")
```

Save the file into the default **/home/pi** folder (eg, as Message.py), then click **Run -> Run Module**. You should see the "It Works" message (without the quotes) scroll through on the Sense HAT's LED matrix display.

Step 9: Retrieving sensor readings

Temperature, humidity and pressure readings can be retrieved from the Sense HAT using the following Python code lines:

```
temp = sense.get_temperature()
humidity = sense.get_humidity()
pressure = sense.get_pressure()
```

Let's write a simple program to display the temperature. Open up a new window in Python (**File -> New File**) and insert the following lines:

```
from sense_hat import SenseHat
sense = SenseHat()
sense.clear()
temp = sense.get_temperature()
temp = round(temp, 1)
print("Temperature =",temp)
```

Save this file (eg, as Environment1.py), then click **Run -> Run Module**. You should see an output in the Python 3 Shell window like that shown in Fig.5. Note the **temp = round(temp, 1)** line; this rounds the reading to one decimal place.

Now that you have that running, let's add some extra code to measure humidity and air pressure as well. In addition, we'll add some extra code so that the readings

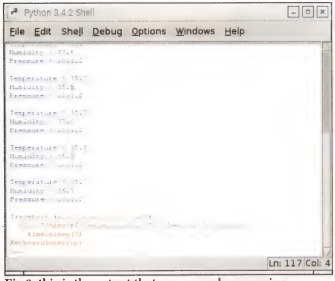


Fig.6: this is the output that appears when running the more complicated code shown below. You stop the program by typing Ctrl-C.

are repeated every five seconds. The code is as follows (be sure to include tabs, as shown):

```
from sense_hat import SenseHat
import time

sense = SenseHat()
sense.clear()

while True:
    temp = sense.get_temperature()
    temp = round(temp, 1)
    print("Temperature =",temp)

    humidity = sense.get_humidity()
    humidity = round(humidity, 1)
    print("Humidity =",humidity)

    pressure = sense.get_pressure()
    pressure = round(pressure, 1)
    print("Pressure =",pressure)

    print()
    time.sleep(5)
```

The **while True:** statement puts the program into a loop (so that the readings are repeated), while the **time.sleep(5)** statement repeats the readings every five seconds.

Note that the lines following the **while True:** statement must be tabbed by the same amount, as shown. In addition, the **import time** statement must also be added near the top of the file, to import the time library. When you run this program, the output will be as shown in Fig.6.

Step 10: Correct the temperature

If the system has been on for some time, the first thing you'll notice about the temperature readings is that they are too high, typically by 10°C or more.

That's due to the readings being skewed by heat from the Raspberry Pi module. Basically, the temperature sensor measures the temperature of the Sense HAT's PCB and this is soaking up heat from the Raspberry Pi module, particularly if it's been on for some time and is running at its full operating temperature.

A lot of the Pi's heat is generated by the ARM7 processor which typically runs somewhere around 44-47°C when the ambient air temperature is 25°C, with additional heat input from the graphics co-processor. The end result is that the Sense HAT's temperature sensor is measuring the system temperature rather than the ambient air temperature, particularly if the two modules are enclosed in the same case.

So what can be done about this? One obvious answer it to physically separate the two modules, preferably using an extension cable. Unfortunately, a 2x20-pin extension cable with a male header on one end and a female header at the other isn't easy to come by.

Another approach is to enclose the Raspberry Pi in a case and mount the Sense HAT module on top of this case, so that it's shielded to some extent from the heat. The Sense HAT module then connects to the Pi's GPIO pins via a stackable header that fits through a matching slot in the top of the case.

That's the approach we adopted for the final version of this project described next month. In addition, we've built a correction factor for the temperature readings into the Python script.

Fairly obviously, the measured air temperature will sit somewhere between the true air temperature and the ARM7's core temperature. Fortunately, the ARM Cortex-A7 CPU has an inbuilt temperature sensor and it only takes a few lines of code to retrieve the reading. So we can retrieve this reading and use it to compensate the temperature reading extracted from the Sense HAT's onboard sensor.

One source on the internet suggested that subtracting the measured temperature (t) from the ARM7's core temperature (ct), halving this and then subtracting the result from the measured temperature would give an ambient temperature (ta) reading that was accurate to with a degree or two. In other words:

ta = t - ((ct - t) x 0.5)

So, for example, if the measured air temperature (**t**) was 35°C and **ct** was 47°C, then the calculated real ambient temperate (**ta**) would be 29°C.

In practice, we found that this gave readings that are about 3°C too high at normal room temperatures, so we modified the equation as follows:

ta = t - ((ct - t) x compensation)

A compensation value of 0.8 rather than 0.5 when the two modules are stacked close together gives an ambient temperature that's accurate to within about 1°C, at least for temperatures ranging from about 20°C to 35°C and with relatively steady ambient temperature.

The Python program shown in the adjacent panel (Environment2.py) incorporates this modified equation, along with a few other enhancements. First, the code including and immediately following the **def get_cpu_temp()** line retrieves the core temperature of the ARM7

Environment2.py

```
from sense_hat import SenseHat
import time
import os

def get_cpu_temp():
    t = os.popen('/opt/vc/bin/vcgencmd measure_temp')
    cpu_temp = t.read()
    t.close()
    cpu_temp = cpu_temp.replace('temp=','')
    cpu_temp = cpu_temp.replace('\'C\n','')
    return float(cpu_temp)

sense = SenseHat()

while True:
    t = 0
    p = 0
    h = 0
    ct = 0
    n = 5
    for x in range(0, n):
        t += sense.get_temperature()
        p += sense.get_pressure()
        h += sense.get_humidity()
        ct += get_cpu_temp()
        time.sleep(0.5)
    t /= n
    p /= n
    h /= n
    ct /= n

    ta = round((t-(ct-t)*0.8),1)
    p = round(p,1)
    h = round(h,1)

    msg = "Temperature = %s, Pressure = %s, Humidity = %s" % (ta,p,h)

    print(msg)
    time.sleep(2)
```

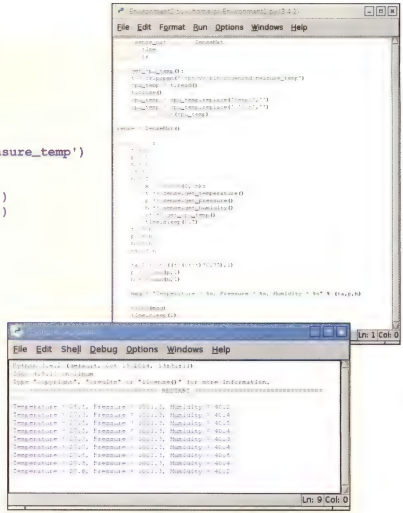


Fig.7: the Environment2.py code corrects for heat soak from the Raspberry Pi module by measure the Pi's CPU temperature & introducing a compoensation factor.

CPU. Then, rather than just take one measurement for each sensor, the program takes five measurements [**n = 5**] at 0.5 second intervals [**time.sleep(0.5)**] and then averages them [**/= n**] to get more accurate readings.

It then calculates the temperature reading and rounds it to one decimal place using the equation

ta = round((t – (ct – t)*0.8),1)

and displays the results for temperature, pressure and humidity.

This entire procedure is then repeated five seconds later [**time.sleep(5)**] for the next set of measurements.

To save you typing it out (and risking errors), the Environment2.py program well be available for download from the Silicon Chip website. By default, it will download into your **/home/pi/downloads** folder. You can move it from there into your **/home/pi** folder if desired.

Fire up Python 3, open the file and run it. You should see a readout as shown in Fig.7. To stop the program, simply click anywhere in the Python Shell window (to make it active) and hit **Ctrl-C** on the keyboard.

You will need an accurate thermometer to calibrate the unit against. If the measured temperature *is* incorrect, adjust the value of the calibration factor in the Environment2.py listing.

Note that you will have to leave the unit running for 30 minutes or so, until its operating temperature stablises, before getting accurate results. In addition, the selected compensation factor will likely only be valid over a fairly narrow range of temperatures (we haven't had a chance to test this yet).

It's also important to note also that the humidity readings will also be affected by any localised heating but we haven't corrected for this.

Step 11: Run it headless

By now, you're probably wondering how you can run the whole shebang without a keyboard, mouse and monitor, especially if you've borrowed these parts for your main PC. That's easily done using a program called TightVNC (VNC = Virtual Network Computing), as detailed in the following section.

That's all for now. Next month, we'll describe how

Running It Headless Using TightVNC

ONCE YOU'VE finished setting up the Raspberry Pi, you'll want to operate it free of the keyboard, mouse and monitor. That way, you can place the Pi anywhere in a room (eg, on a bookshelf) with nothing more than the power cable from the plugpack running to it.

However, it's a good idea to first set it up so that you can control it using another computer. That way, you'll be able to change settings and even cleanly shut it down if necessary.

The best way to do this is to install a VNC (Virtual Network Computing) server on the Raspberry Pi. This will allow you to view the Pi's desktop (or GUI) from a Windows, Mac or Linux PC. It's also necessary to install a VNC viewer on the PC, to make the connection. The Pi's desktop then appears as a separate window on the PC's desktop and you have complete control.

We're using TightVNC for this project. It's installed on the Raspberry Pi by opening the Terminal and issuing the command:

```
sudo apt-get install tightvncserver
```

When the installation is complete, start the server as follows:

```
vncserver :1 -geometry 1280x800 -depth 24
```

The first time you do this, you'll be asked to create a password which the PC user must use to connect to the Pi. This password should be limited to eight characters, otherwise it will be truncated (note that no characters will appear as you type the password). You'll also be asked if you want to set a read-only password but that's optional.

Once that's done, a message will confirm that the settings have been saved in **/home/pi/.vnc** and that virtual desktop 1 has been created, ie: **New 'X' desktop is raspberrypi:1**

We now want TightVNC to automatically start when the system is booted. To do that, launch **sudo leafpad** from the Terminal, create a new file called **vncserver.service** in **/etc/systemd/system** and add the following code:

```
[Unit]
description=Remote Desktop Server
After=syslog.target network.target

[Service]
User=pi
Type=forking
PAMName=login
ExecStart=/usr/bin/vncserver :1 -geometry 1280x800 -depth 24

[Install]
WantedBy=multi-user.target
```

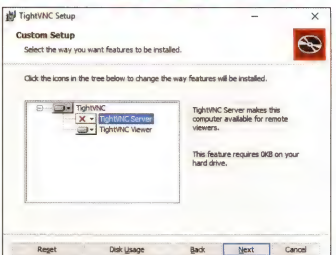


Fig.8: you only need TightVNC Viewer on the remote PC, so deselect the server option during installation.

You then need to change the file so that it is owned by root, make it executable and ensure it starts during boot as follows:

```
sudo chown root:root /etc/systemd/system/vncserver.service
sudo chmod 755 /etc/systemd/system/vncserver.service
sudo systemctl enable vncserver.service
```

Reboot the system (**sudo reboot**) to get it running correctly.

Windows client

The next step is to install a VNC client (or viewer) on your PC. If you are using a Windows computer, go to www.tightvnc.com and download the TightVNC software. Both 32-bit and 64-bit versions are available; be sure to choose the correct one for your version of Windows.

Double-click the downloaded file to begin the installation process and choose the Custom option. You only need to install the viewer, so deselect the TightVNC Server option (see Fig.8), then click Next and deselect the firewall option in the following dialog.

That done, complete the installation, then launch TightVNC Viewer (see Fig.10) and click the Options button to open the Connections Options dialog. Drag the Compression Level and JPEG sliders to "best" (you

to install Apache Web Server so that you can access the sensor readings over the internet via a web browser. This will also allow you to change the compensation setting, alter the number of displayed readings and change the time interval between readings simply by entering the values at the end of the URL (web address).

Finally, we intend to mount the Raspberry Pi in a clear Perspex case, with the Sense HAT module mounted on the outside and connected to the Pi via a stackable header to separate the two and minimise heat problems.

can adjust these back later to improve speed if necessary), then set the Mouse Cursor option to "Don't show remote cursor" and the Local Cursor Shape to "Arrow". The remaining options can stay at the defaults.

Connecting to the Pi

You're now ready to connect to the Raspberry Pi from your Windows computer. All you have to do is launch TightVNC Viewer, enter the Pi's IP address followed by **:1** in the dialog and click Connect.

For example, if the Pi's IP address is 192.168.0.46, you would enter: 192.168.0.46:1 How do you know what the Pi's IP address is? Simply hover the mouse over the WiFi icon on the Pi's taskbar and it will tell you. Alternatively, issue the **ifconfig** command in a Terminal window and again the IP address for wlan0 (or eth0 if you're using a wired Ethernet connection) will be listed.

That's it; you can now operate your Raspberry Pi without a mouse, keyboard or monitor.

If you're using Linux on the remote computer, it will probably already have a VNC client (Vinagre) installed. Alternatively, for a Mac, try VNC Viewer or use the inbuilt Screen Sharing app (Google it).

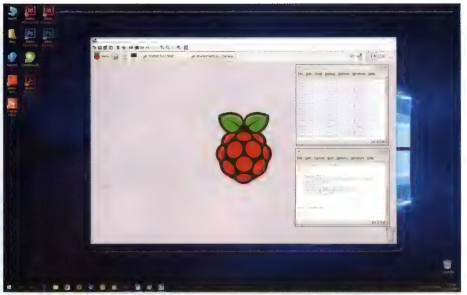


Fig.9: this screen grab shows the Raspbian desktop running in a TightVNC window on a Windows 10 PC. This gives you full remote control over the Raspberry Pi module.

Fig.10: you connect to the Pi from your PC by typing in its IP address followed by ":1" (without the quotes).

Tidying up

By default, you will not be able to copy and paste from any applications running in the Raspberry Pi window and any local applications on your PC. To fix that, you first need to install **autocutsel** using the command:

```
sudo apt-get install autocutsel
```

You then use the Nano text editor to modify the **xstartup** file in the hidden **.vnc** folder. That's done by opening the file using **nano /home/pi/.vnc/xstartup** and inserting the line **autocutsel -fork** as follows:

```
#!/bin/sh

xrdb $HOME/.Xresources
xsetroot -solid grey
autocutsel -fork
#x-terminal-emulator -geometry 80x24+10+10
-ls -title "$VNCDESKTOP Desktop" &
#x-window-manager &
# Fix to make GNOME work
export XKL_XMODMAP_DISABLE=1
/etc/X11/Xsession
```

Save this file (**Ctrl-O**) and restart the VNC server (reboot-ing the Raspberry Pi is the easiest way to do this). You will then be able to cut and paste between the two desktops on the PC.

Another problem arises if you try to run a GUI application as root; ie, using sudo. This will immediately result in a message informing you that you are not authorised to connect.

The way around this is to issue the command **xhost +** in the Terminal. This gives all users access to the Raspberry Pi's display or you can restrict root access to a particular user by using **xhost + hostipaddress**, where hostipaddress is the ip of the authorised user (eg, **xhost + 192.168.0.10**).

How secure is it?

TightVNC uses ports 5800 & 5900 to communicate with the outside world, so provided you keep these ports closed on your router, you should be safe from internet hacks.

In short, don't do it unless you use a very strong password. Even then, it's a bit of a security risk since all traffic except for the password is unencrypted. The way around this is to install an SSH (secure shell) server and use an SSH tunnel for TightVNC connections (details next month).

Fixed IP address

Finally, by having the Raspberry Pi pick up its IP address from your router's DHCP server, there's always a risk that this IP can change if the power is interrupted. If that happened, you would no longer know the IP address when attempting to connect using TightVNC Viewer.

A dynamic IP can also complicate matters when connecting to the Pi's web server, especially over the internet.

For this reason, it's best to have the router issue a fixed IP address to the Raspberry Pi. We'll show you how in Pt.2 next month. **SC**

By Nicholas Vinen

High-performance stereo valve preamplifier

This stand-alone stereo valve preamplifier is based on the Currawong amplifier (November 2014-January 2015) but has a new power supply which runs off a low-voltage DC supply. It has very good performance, especially for a valve preamp, with low distortion and a very high signal-to-noise ratio of 105dB. It's easy to build too, with the preamp and power supply all on one PCB.

OUR FIRST VALVE preamplifiers were single-channel (mono) designs based on the 12AX7 twin triode (in the November 2003 and February 2004 issues). That design was also incorporated into the Currawong valve amplifier mentioned above. However, we have had a number of requests for a stereo version of the preamp and when we looked at the original mono design from 12 years ago, we realised that we could make a number of significant improvements.

So for a start, this new design is stereo so you don't need to build two separate units (which involved at least three PCBs). It also has a more compact and improved switchmode power supply which is on the same board as the rest of the components

Also, the earlier design had exposed components on the top of the board which operated at 250V DC, necessitating the application of silicone sealant to render it safe – not a very attractive option. The new design still "shows off" its components but they are visible through a clear acrylic case, protecting the user from electric shocks.

The overall performance is quite a lot better than the earlier design. Take a look at the graphs from our Audio Precision System Two, shown

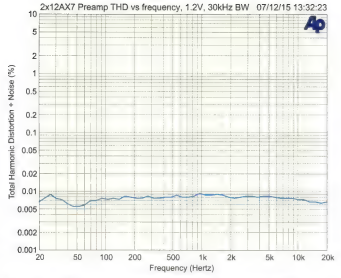


Fig.1: total harmonic distortion plotted against frequency for an input of 300mV RMS and an output of 1.2V RMS (full power for a typical power amplifier). The measurement bandwidth is 30kHz in order to chop out any residual switching artefacts from the power supply while still measuring some of the harmonics of higher audio frequencies. The result is essentially flat with frequency.

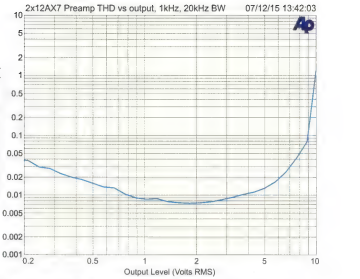


Fig.2: distortion versus output amplitude. For signals below 1V (ie, <250mV RMS input), noise starts to affect the measurement while for signals above 3V RMS out, the intrinsic second harmonic distortion of the valve begins to dominate. Distortion rises dramatically for outputs above about 9V RMS as parasitic capacitances interact with the higher slew rate.

in Figs.1-4. If you compare these to the graphs for the mono preamp in the February 2004 issue (pages 32 & 33), you will see that this is a big improvement with lower distortion across the board and no high-frequency rise. The frequency response is pretty flat, with a very slight rise in response at both 20Hz and 20kHz, due to reduced feedback effectiveness at these extremes.

One of the changes in our circuit is that we've put the volume control pot at the input end rather than the output end. This greatly reduces the chances of overload and gives lower output impedance and lower valve plate loading. In theory, it would increase the noise but in practice this design has ended up with a better signal-to-noise ratio.

Besides stereo music, another application for a 2-channel valve preamp might be for use as a musical instrument preamplifier, either with two mics on one instrument or two separate instruments. For this application, we have provision for a mixed output with a pot that controls how the two inputs are mixed. This pot, and its associated RCA connector, can be left off for stereo applications.

Since 12AX7 filaments are designed to run from 12.6V, the circuit has been designed to run off 15V DC, with an on-board regulator providing the correct filament voltage. However, we have tested the preamp with a 12V DC supply and it had little effect on performance so that is a valid option. A 12V automotive supply should be fine as it will normally be above 12.6V most of the time (assuming the battery charge state remains high).

Features & Specifications

- Stereo preamplifier with volume control
- Uses two 12AX7 dual triodes (socketed)
- Variable gain: -100dB to +12dB
- Low distortion: <0.01% THD+N @ 20Hz-20kHz, 1.2V output (see Figs.1 & 2)
- Flat frequency response: +1,-0dB 20Hz-20kHz (see Fig.3)
- Channel separation: >85dB @ 1kHz, >60dB @ 20kHz (see Fig.4)
- Signal-to-noise ratio: 105dB relative to 1V input (20Hz-20kHz bandwidth)
- Power & HT presence indicator LEDs
- RCA socket inputs & outputs
- Power supply: 13-15V DC @ 650mA
- Power supply reverse polarity protection
- Onboard power switch
- No transformer winding necessary
- Optional mixed output for use with musical instruments.
- Fits in a custom-designed clear laser-cut acrylic case

Circuit description

The full circuit is shown in Fig.5. Both channels are shown in full, along with the power supply, although the operation of the two channels is identical.

Looking at the left channel only, the signal comes in via RCA socket CON1 and passes through an RF-rejecting low-pass filter comprising a 100Ω resistor with a ferrite bead on one of its leads and a 100pF ceramic capacitor. The signal is then AC-coupled to 50kΩ volume control potentiometer VR1a via a 470nF MKT capacitor.

The attenuated signal is then AC-

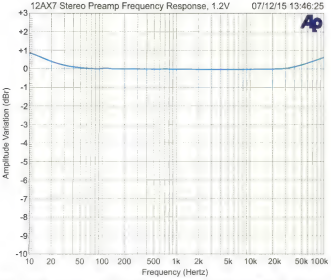


Fig.3: the frequency response for the preamplifier is quite flat but there is a slight rise in the response below 50Hz due to the increasing impedance of the feedback circuit; feedback starts to drop off, allowing the gain to rise. There is a similar rise above 30kHz, however this is well above the audio band. A small bump is visible at 100Hz due to low levels of mains hum being picked up.

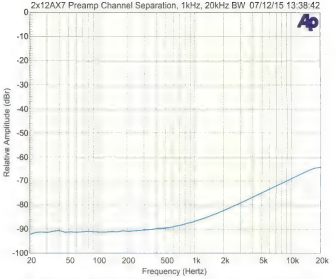


Fig.4: channel separation is very good, being more than 90dB below 400Hz, rising to around -65dB at the upper end of the audio band. This was measured with the other channel input terminated with a low impedance. The signal coupled through from one channel to the other at higher frequencies is relatively undistorted so should not result in undesirable intermodulation.

coupled to the grid of triode V1a via another 470nF MKT capacitor and a 22kΩ RF stopper. This stopper is quite important. Without is, a fair bit of hash from the power supply can couple into the valve and then be amplified. A 1MΩ bias resistor shunts any grid leakage to ground and biases the grid to near-0V.

V1a operates with a current of around 360µA, set by the combination of its 270kΩ anode resistor and 3.3kΩ cathode resistor. The amplified signal at its anode is coupled to the grid of V1b with a 220nF capacitor and the grid is biased with another 1MΩ resistor to ground.

Since V1b needs to handle a higher signal voltage, it runs at around 1.5mA, set by its 68kΩ anode resistor and 680Ω cathode resistor. The output at its anode is coupled to output connector CON3 via another 220nF capacitor, with a 1MΩ resistor setting the DC level to 0V.

AC-coupled negative feedback

The same output signal is also fed back to V1a's cathode via a pair of parallel 470nF capacitors and a 10kΩ resistor. The 10kΩ resistor forms a 4:1 voltage divider with V1a's 3.3kΩ cathode resistor. Say a 100mV positive step is applied to V1a's grid. This will turn V1a on harder, pulling its cathode negative and thus V1b's grid will be pulled negative. That will cut off V1b in turn, causing its anode voltage to rise. Once its anode voltage has risen by 400mV, the 4:1 divider will have caused V1a's cathode to increase by 100mV.

Since it's the grid-cathode voltage which determines how much current a valve conducts, the 100mV increase in V1a's cathode voltage effectively cancels out the 100mV increase in its grid, so it will be back to conducting roughly the same current it was initially. As its anode swing is a tiny fraction of the anode voltage of around 150V, it will therefore reach a steady state. Thus overall gain of the circuit is accurately set to 12dB by this negative feedback network.

Mixed & panned outputs

The preamp is intended to be used in stereo applications, with the two channels handling independent signals. However, it could be used as a musical instrument preamplifier. In this case, you can use it as two mono preamplifiers with the two outputs mixed together. For this configuration, VR2 and CON5 are installed and CON3/CON4 can be omitted.

In this case, the output of each channel is mixed by VR2. VR1 still controls the overall output level and with VR2 at mid-setting, an equal amount of each input signal is mixed into the output. As VR2 is rotated clockwise, the output contains more of the amplified signal from CON2 and less of that from CON1 and the opposite is true if it's rotated anti-clockwise.

Basically, VR2 can be regarded as a pan control, panning from one channel to the other.

Note that if VR2 is fitted, V1b and V2b are loaded with around 50kΩ and the output impedance is increased. Still, as long as the device being fed

WARNING! HIGH VOLTAGES

High DC voltages are present in this circuit. In particular, the power supply produces an HT voltage of up to 285V DC and this voltage and other high DC voltages derived from it are present on various parts of the circuit.

Do not touch any part of the circuit when power is applied otherwise you could get a severe or even fatal electric shock.

The red LED (LED2) in the circuit indicates when high voltages are present. If it is lit, the power supply and various parts on the PCB are potentially dangerous. **Before applying power, the completed preamplifier must be mounted in a suitable case and fitted with a Perspex cover as described in Pt.2 next month to ensure safety.**

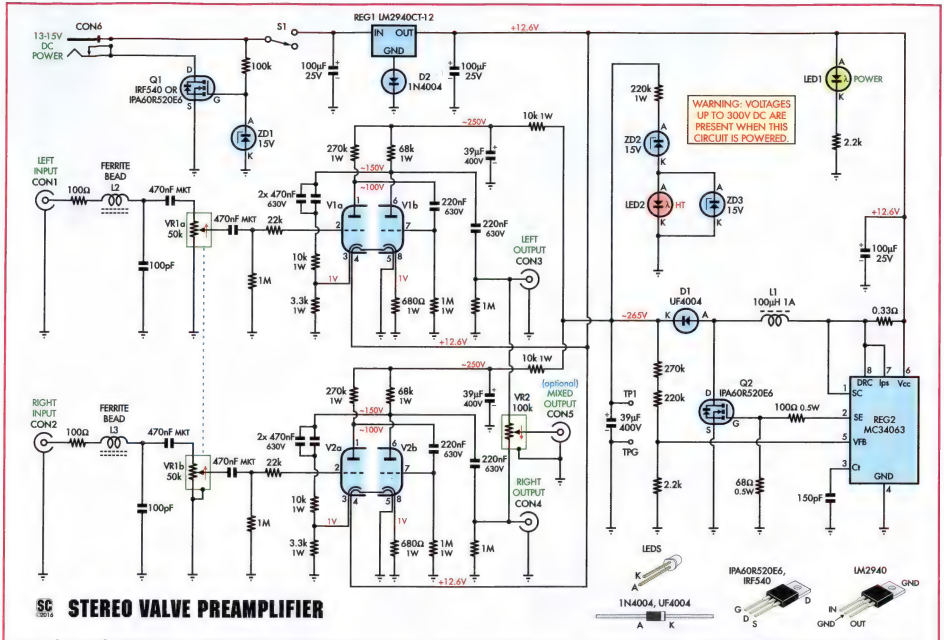
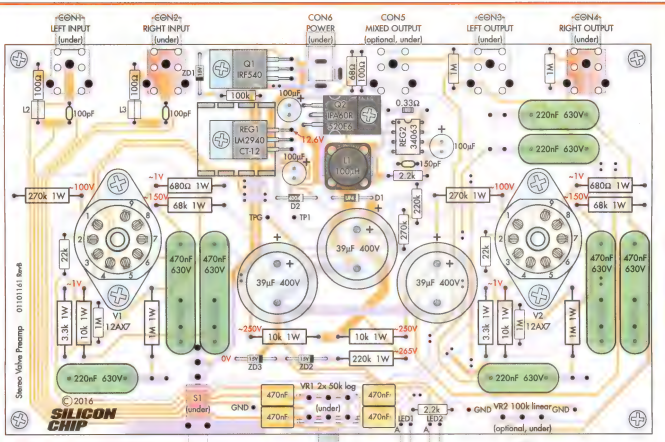


Fig.5: the complete stereo valve preamplifier circuit. Each channel uses a 12AX7 dual triode with an overall gain of four times (12dB). Amplification is done in two stages, with negative feedback around both to set the gain and also cancel distortion. The circuit runs off a nominal 15V power supply which is regulated to 12.6V for the filaments, while a ~265V HT rail is produced by switchmode regulator REG2 and high-voltage Mosfet Q2.



WARNING: HIGH DC VOLTAGES (UP TO 285V) ARE PRESENT DURING OPERATION

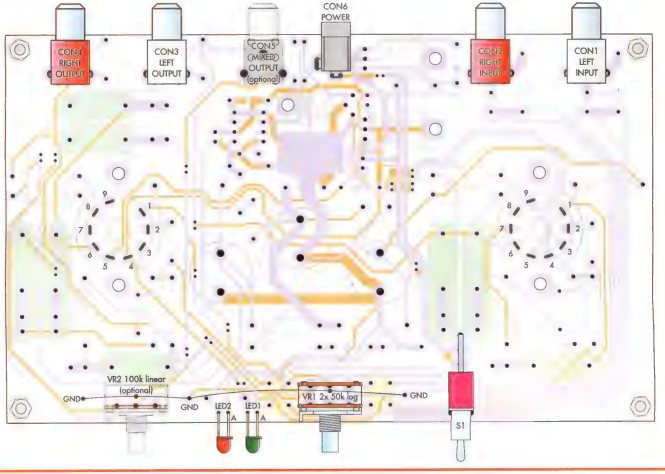


Fig.6: top and bottom PCB overlay diagrams. Use these as a guide when assembling the PCB. Start by fitting the components to the top side, which is everything except the connectors, power switch, pots and LEDs. Note the wires used to earth the pot bodies to the nearby GND pads. Leave VR2 and CON5 out if building a stereo preamplifier. CON3 and CON4 are optional if VR2 & CON5 are fitted.

has a relatively high input impedance, this should not be a problem.

Power supply

A DC input of around 13-15V is required at CON6. As mentioned earlier, supply voltages down to 12V are acceptable however the filaments of V1/V2 will run at lower power than they are designed for.

Mosfet Q1 provides reverse polarity protection, with much lower voltage loss than a simple diode, even a Schottky type. If the supply polarity is correct, Q1's gate is pulled positive with respect to its source and so ground current can flow back to CON6 normally. However, if the supply polarity is reversed, Q1's gate is pulled negative and thus its channel will not conduct. Its body diode is also reverse biased in this condition so the only current that will flow is a few microamps through ZD1 and its series 100kΩ resistor.

ZD1 protects Q1 in case the supply voltage spikes above 20V for more than a very brief period.

Power switch S1 interrupts the supply to REG1, a low-dropout automotive 12V regulator. Its ground pin is "jacked up" by around 0.6V by diode D2, increasing its output to around 12.6V to suit the filament requirements of the 12AX7 valves. 100µF input bypass and output filter capacitors are provided and these should ideally be low-ESR types for supply stability.

LED1 indicates the presence of the 12.6V rail. As well as running the filaments directly, this rail also supplies switchmode regulator REG2 which is configured as a boost regulator to produce the HT supply.

When REG2's internal transistor is switched on, current flows through the 0.33Ω shunt, into pin 1 (switch collector), out of pin 2 (switch emitter) and through a voltage divider formed by 100Ω and 68Ω resistors. The voltage produced by this divider drives the gate of high-voltage logic-level Mosfet Q2.

So when REG2's internal switch is on, Q2 is biased into conduction and it pulls current through the 0.33Ω shunt and inductor L1 to ground. This charges up L1's magnetic field. REG2 has an internal oscillator that we've set to around 100kHz using a 150pF capacitor from pin 3 (Ct) to ground. L1 continues to charge either until the ~7.5µs period set by this oscillator expires or the current builds to around 1A, at which point the voltage across the 0.33Ω shunt exceeds the ~300mV current trip level, as sensed by pin 7 (Ips).

In either case, REG2's internal transistor is switched off and the 68Ω resistor quickly pulls Q2's gate to 0V, switching it off. This causes the magnetic field in L1 to begin collapsing, which continues to "push" current through the inductor in the same direction as it was flowing before it was interrupted.

Since the "input" side of L1 is still connected to the 12.6V supply, the only way for current to continue to flow is for high-voltage ultrafast diode D1 to become forward biased. As a result, the voltage at D1's anode increases dramatically. Before L1's magnetic field can collapse completely, the oscillator in REG2 causes its internal transistor to switch back on, recharging it and repeating the cycle.

When the circuit is first powered up, the voltage at D1's cathode will start at around 12V but as the three 39µF 400V capacitors charge up, this voltage will continue to rise until it reaches nearly 300V.

One of two things then happens. The voltage is either limited by the fact that the current limit enforced by REG2 prevents any more energy flowing into L1 in each cycle than is consumed by V1 and V2, or the voltage rises high enough that the voltage at the voltage feedback pin of REG2 (pin 5) rises above 1.25V. If this happens, REG2 will skip pulses until the output voltage drops, then it will switch back on to regulate said voltage to the set level.

However, we have designed this circuit so that it can't quite produce a high enough output voltage to regulate properly. This is because the pulse skipping that's used to regulate the output voltage causes sub-harmonics of the 100kHz switching frequency to

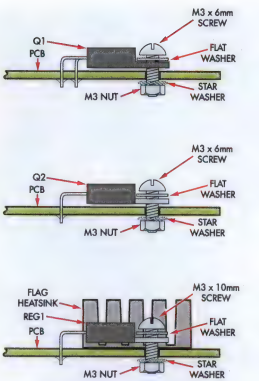


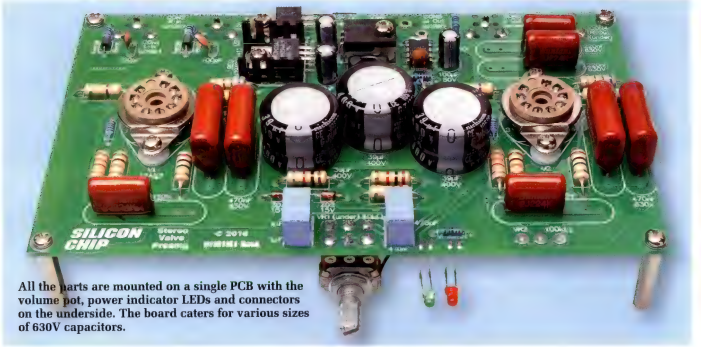
Fig.7: mounting details for Q1 (top), Q2 (middle) and REG1 (bottom). Note that a longer machine screw is used for REG1 and that Q1 is in a fully insulated package with its centre lead bent over and soldered closer to the body than the other two.

be radiated and depending on how many pulses are skipped, these could be in the audio band (ie, below 20kHz) and could couple into the preamplifier, reducing its signal-to-noise ratio.

This means that the HT voltage is not actually regulated but that isn't much of an issue as the 12AX7s will run happily off quite a wide range of voltages; anywhere in the range of 250-300V will do. The feedback divider really only exists to prevent damage in case one or both valves are removed, fails or becomes disconnected during operation. In this case, it will limit the HT rail to around 285V DC.

The actual operating HT voltage will depend on a few factors but mainly on the exact value of L1, the 0.33Ω shunt, REG2's current limit voltage sense threshold and the 150pF capacitor. These all affect how much energy L1 can store for each cycle, or in the case of the 150pF capacitor value, the maximum number of charge cycles per second.

We've set the circuit up so that in most cases, the actual HT voltage produced should be high enough for



All the parts are mounted on a single PCB with the volume pot, power indicator LEDs and connectors on the underside. The board caters for various sizes of 630V capacitors.

correct operation but not so high that pulse skipping is employed (ie, below the ~285V regulation target). In our prototype, it reaches 280V after about 30 seconds and eventually drops to about 265V once the valves have fully warmed up.

Construction

All parts are carried on the main PCB and assembly is quite straightforward. It should only take a couple of hours for experienced constructors. The board itself is coded 01101161 and measures 170 x 102mm. Referring to the PCB top side overlay diagram Fig.6, begin by fitting all the smaller resistors.

It's best to check all the resistor values with a DMM before fitting them. Don't forget that the 68Ω and 100Ω resistors must be 0.5W types and that two of the other 100Ω resistors have ferrite beads slipped over their leads before they are soldered in place. The 0.33Ω resistor should also be fitted now, whether it's a through-hole or SMD type.

Follow with diodes D1 and D2 and zener diodes ZD1-ZD3. Don't get the three different types mixed up and pay careful attention to polarity. This is indicated by the cathode stripes shown on Fig.6 and the PCB silkscreen.

Having done that, solder inductor L1 in place. This is most easily done by first applying a little flux paste to the pads, then adding some solder to one of the pads – the right end if you are right-handed or left if you are left-handed. Then place the inductor next to its final position, heat the solder on that pad and slide the component into place.

You will find that once it contacts the solder, it will take a few seconds to heat the component up to the point where it will adhere and you can then move it into its final location. It's then just a matter of adding solder to the opposite pad and continuing to heat it until it adheres to both the pad and component lead. Finally, go back to the other side, add some fresh solder and heat it further, again making sure it forms a good fillet.

Next, solder REG2 to the board. Don't use a socket and make sure its pin 1 dot is at upper-left as shown on Fig.6. Press it down flat on the PCB before soldering the pins. Follow with the larger (1W) resistors, using a similar procedure as before.

Now bend the leads of Q1 and Q2 down through 90° about 5mm from the body of each component and attach them to the board using M3 x 6mm machine screws and nuts, with a shakeproof washer under each nut and a flat washer under the head. Don't get these two components mixed up – Q2 should be encapsulated in black plastic while Q1 may have a metal tab (if you are using an IRF540) – see Fig.7 for details.

Once the screws are done up tightly and the parts checked for proper alignment, solder and trim the leads.

Having done that, solder the ceramic and MKT capacitors in place. These can all go in either way around, as they are non-polarised. Refer to Fig.6 to see which value goes where.

Now fit regulator REG1. The procedure is the same as for Q1 and Q2 except that a flag heatsink is positioned under the regulator's tab and an M3 x 10mm machine screw is used to secure it instead of an M3 x 6mm screw. Make sure that the regulator's body and heatsink are square and that the screw is done up tightly before soldering the leads – see Fig.7.

Fitting the valve sockets

The valve sockets are retained mechanically, to avoid placing stress on the solder joints when inserting and removing the valves. Each is held in place with two M3 x 10mm machine screws, with a Nylon nut and two Nylon washers used to form a spacer. Fit a shakeproof washer under the nuts (see the photos for details).

Basically, it's just a matter of inserting an M3 x 10mm machine screw through the top of the two mounting holes on the valve socket and screwing a Nylon nut onto each thread. Do the nuts up tight, then slip pairs of Nylon washers over each screw shaft and feed these through the mounting holes on the PCB. You'll need to coax the nine solder tabs into the slots on the PCB, then the whole thing should drop into place.

Use the shakeproof washers and

nuts to fasten it in place, make sure the nuts are done up tightly, then solder and trim the nine tabs on each socket.

You can now solder the three small and three large electrolytic capacitors in place (see Fig.6). In each case, make sure that the longer lead goes through the hole nearest the + symbol.

Underside components

Now it's time to fit the components on the other side of the board – see Fig.6. The RCA connectors fitted are CON1-CON4 (for a stereo preamplifier) or CON1, CON2 and CON5 (mixed mono preamplifier for instruments). CON1 and CON3 are white, CON2 and CON4 are red and CON5 can be black.

Unfortunately, white RCA sockets aren't that easy to come by. We sell a set of four on our Online Shop, including red, white, black and yellow. These have a slightly different footprint to the types available from Jaycar and Altronics but as you can see from our prototype, the leads can be bent so that they fit. In fact, they are a little easier to fit than the other type and as a bonus, have a consistent mounting height, unlike some types which can vary between different colours.

Whichever sockets you are fitting, make sure they are pressed down fully onto the PCB and are perpendicular to the board edge before soldering the three pins. You can also fit DC socket CON6 now, on the same side of the board, again making sure it's nice and square before soldering.

Before fitting the pot(s), you will need to use a file to scrape off a small area of the passivation on top of the body so that you can solder an earth wire in place. Basically, it's just a matter of holding the body in a vice using a couple of scrap pieces of timber to prevent damage and then a few passes with a file should reveal a shiny surface. Don't breathe in the dust produced; it may be toxic.

If your pot(s) have long shafts, you will also want to cut them short now. Use a hacksaw and file to cut it/them to no more than 15mm. Then, referring to Fig.6, solder the pot or pots in place on the underside of the board. Solder some tinned copper wire between the provided GND pads, across the top of the pot body(s), then solder the wire to the pot(s) to "earth" them.

Now fit power switch S1 in place, making sure it's first pushed down fully onto the PCB. Finally, install LED1 and LED2. Check Fig.6 to determine the required orientation, then bend the LED leads through 90° 6mm from the base of the lenses. Solder the LEDs in place on the underside of the board, with the horizontal portion of the leads 13mm from the bottom of PCB. This may be easier to do if you cut a 13mm cardboard spacer first.

Testing

The first step is to check that the HT power supply is working but before doing this, temporarily attach the four tapped spacers in each corner using an M3 machine screw.

Test points are provided to monitor the HT voltage, near the centre of the PCB, however it's easier and safer to use DMM alligator clip leads to connect to the anode of ZD3 (negative lead) and the right-hand end of the 220kΩ 1W resistor (positive lead) – see the 0V and ~265V markings on Fig.6. Set your DMM to a range which will read 300V DC and plug the power supply into the PCB but not the mains.

. . . continued on page 96

Parts List

1 double-sided PCB*, code 01101161, 170 x 102mm
1 set of clear acrylic laser-cut case pieces*
1 small tube acrylic adhesive
4 rubber feet
1 15V 1A plugpack
2 12AX7 dual triode valves
2 9-pin valve sockets (Jaycar PS2082)
1 100µH 12x12mm SMD inductor* (L1) (Murata 48101SC; element14 2112367)
1 50kΩ 16mm dual log pot (VR1)
1 100kΩ 16mm linear pot (VR2; optional, see text)
2 knobs, to suit VR1 & VR2
1 mini TO-220 flag heatsink, 6073B type
2 ferrite beads (L2,L3)
2 white switched RCA sockets (CON1,CON3)*
2 red switched RCA sockets (CON2,CON4)*
1 black switched RCA socket (CON5; optional, see text)*
1 PCB-mount DC socket to suit plugpack (CON6)
1 PCB-mount right-angle mini SPDT toggle switch (S1) (Altronics S1320)
2 M3 x 6mm machine screws
5 M3 x 10mm machine screws
4 M3 x 32mm machine screws
7 M3 shakeproof washers
3 flat washers, 3mm I.D.
7 M3 nuts
4 M3 Nylon nuts
8 Nylon washers, 3mm I.D.
4 M3 x 12mm Nylon machine screws
4 6.3mm M3 tapped Nylon spacers
4 12mm M3 tapped Nylon spacers
4 25mm M3 tapped metal spacers
1 200mm length 0.7mm diameter tinned copper wire

Semiconductors

1 LM2940CT-12 12V 1A low-dropout regulator (REG1)
1 MC34063 switchmode regulator (REG2)
1 IRF540 or IPA60R520E6* N-channel Mosfet (Q1)
1 IPA60R520E6* 600V N-channel Mosfet or equivalent (Q2)
1 green 3mm LED (LED1)
1 red 3mm LED (LED2)
3 15V 1W zener diodes (ZD1-ZD3)
1 UF4004 ultrafast diode or equivalent (D1)
1 1N4004 1A diode (D2)

Capacitors

3 100µF 25V low-ESR electrolytic
3 39µF 400V low-profile snap-in electrolytic (Nichicon LGJ2G390MELZ15* from Mouser)
4 470nF 63V MKT
4 470nF 630V metallised polyester
4 220nF 630V metallised polyester
1 150pF disc ceramic
2 100pF C0G/NP0 disc ceramic

Resistors (1W, 5%)

2 1MΩ, 2 10kΩ, 2 270kΩ, 2 3.3kΩ, 1 220kΩ, 2 680Ω, 2 68kΩ

Resistors (0.25W, 1%)

4 1MΩ, 2 2.2kΩ, 1 270kΩ, 1 100Ω 0.5W, 1 220kΩ, 2 100Ω, 1 100kΩ, 1 68Ω 0.5W, 2 22kΩ, 1 0.33Ω through-hole or SMD 1206 resistor*

* Available from the SILICON CHIP Online Shop; details in next month's issue.

High-visibility 6-digit GPS clock; Pt.2

Last month we introduced our GPS high-visibility 6-digit LED clock. But we should emphasise its main feature: it automatically changes time zones as you travel around the country; important if you are cruising the world on a yacht or just touring around the country. This second article gives all the info to build and use the clock.

WE'RE VERY pleased with this clock because its big, bright display is so eye-catching and can be viewed from quite some distance away. It also has quite a few features beyond just displaying the time, as will become apparent when you read the operating instructions below.

Last month, we mentioned that you can use a module with RS-232 signalling but that TTL is preferred. Modules with RS-232 signalling have a bipolar voltage swing on their serial port pins of between ±3V and ±15V. This allows longer cable runs and improves noise immunity.

But with the module only a few centimetres away from the microcontroller this is unnecessary and only complicates interfacing. As a result, many GPS modules simply use a 0-3.3V (or thereabouts) swing, ie, TTL levels and the signals are inverted too.

You may get a better deal on an RS-232 module and in this case you can simply wire a resistor of say 4.7kΩ-10kΩ between the GPS module's TX line and the clock's RX pin. The microcontroller's internal clamp diodes will then limit the applied voltage to a safe level.

This works despite the signal inversion because if the clock detects gibberish from the GPS module, it tries inverting the signal level. If that doesn't work, it will also try various baud rates from 2400 bps up to 115,200 bps with both inverted and non-inverted sense until it detects valid NMEA data. The most common rates of 4800 and 9600 baud are tried first.

By the way, GPS modules are now becoming available with GLONASS support. GLONASS is a GPS competitor built by Russia and modules which support this will typically work better indoors or in poor signal areas because they have access to more satellites – in other words, they can use both GPS and GLONASS satellites to get a fix.

Last month we mentioned that the u-blox Neo-6M is available for around US$10.42 but you might also want to consider the Neo-7M for around $20

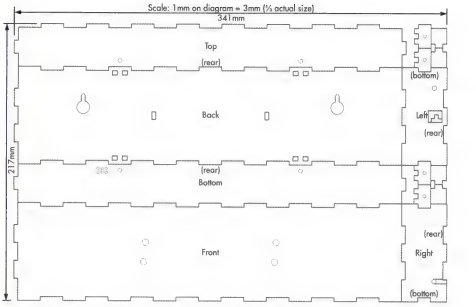


Fig.4: this diagram shows how the single sheet of 350 x 225mm (or larger) acrylic is cut up into the six large pieces and six smaller pieces that are then glued together to form the case. Cutting takes about five minutes. The case includes slots for wall-hanging and some holes to make the piezo sound louder.

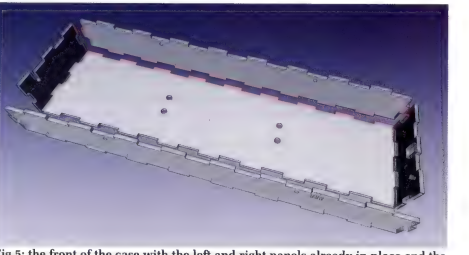


Fig.5: the front of the case with the left and right panels already in place and the top and bottom about to be glued. The red shaded areas show where adhesive would need to be applied for the top panel to be glued although as stated in the text, you could apply adhesive to only the top piece as long it's applied to all the faces that will contact the shaded ones. Note carefully the hole positions in the four surrounding panels so that you glue them with the correct configuration.

which is very similar to the 6M but also has GLONASS support.

We should point out that like most other modules, both the Neo-6M and Neo-7M come with ceramic patch antennas but these are external antennas connected via a short cable. This means you could in theory connect it to a larger external antenna.

Testing

There isn't much to testing the clock. The simplest method is to power it up briefly. There might be a short delay (of no more than a few seconds) while the supercap charges up but it should then immediately perform a display test where each segment on all the digits lights up in turn and then the piezo buzzer will sound a 100ms beep.

If that doesn't happen after a few seconds, switch off and check for faults such as incorrectly installed components or bad solder joints. You can also check that the output voltages of REG1, REG2 and REG3 are correct.

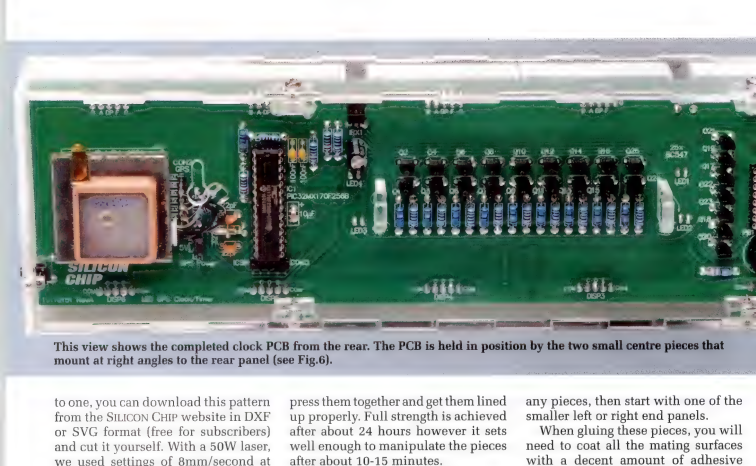
After the test procedure, IC1 will fire up its 32kHz oscillator. If you get the digit test but nothing else, check for the presence of the 32kHz signal on pin 11 of IC1. If that's missing, it may be that one of the leads of crystal X1 is shorted to the case or some other adjacent metalwork.

If a GPS module is detected, the unit will indicate that it is waiting for a position fix by showing "GPS" on the display, along with a progress display. Otherwise, the clock will flash "12:00:00" until you set the date and time (see below for information on how to do this). Assuming it's working, you can move on to making the case.

Assembling the case

The case is made from a single piece of clear or tinted acrylic which starts out at 350 x 225mm and is laser-cut into six large pieces plus a number of smaller pieces, which are then glued together. The back is not glued on; it's held with four self-tapping screws so that it can be removed to allow access to the PCB module for maintenance. The cutting pattern is shown in Fig.4.

If you have a laser cutter, or access



This view shows the completed clock PCB from the rear. The PCB is held in position by the two small centre pieces that mount at right angles to the rear panel (see Fig.6).

to one, you can download this pattern from the SILICON CHIP website in DXF or SVG format (free for subscribers) and cut it yourself. With a 50W laser, we used settings of 8mm/second at 80% power. **We can also supply pre-cut case kits from our online shop, together with the PCBs, programmed microcontrollers and some of the 7-segment displays.**

You can use clear acrylic, as shown on our prototype or acrylic tinted with a colour that matches the displays (ie, green, blue, red, etc). You will see more of the workings of the clock with the clear case but the tinted case may provide better contrast for the display. The clear case is suited to any display colour whereas a tinted case will need to match the display colour used.

The case is glued using a special solvent-based adhesive that makes very strong bonds between pieces of acrylic. You could use cyanoacrylate (super glue) in a pinch but we can't guarantee that the result would last.

We used SciGrip Weld-On 16, fast-setting "clear, medium-bodied solvent cement". It states on the label that it's suited for Butyrate, Polycarbonate, Styrene and Acrylics. You are unlikely to find this type of adhesive in a hardware store but should be able to get it from a plastic supplier. Ours came from Plastix [Sydney: (02) 9567 4261, Northern Beaches: (02) 9939 0555].

This forms a strong bond quickly so you have about a minute to apply the adhesive to the pieces to be mated, press them together and get them lined up properly. Full strength is achieved after about 24 hours however it sets well enough to manipulate the pieces after about 10-15 minutes.

The bond is clear but you don't want to get excess adhesive on the material as it will affect the surface finish and you definitely don't want to drip it on the front face. It tends to get a bit "stringy" (sort of like melted mozzarella) after coming on contact with the acrylic. Keep a clean (disposable) rag on hand to mop up any excess adhesive. Also make sure you have a large, clean, flat surface to lay the pieces down on, eg, lay down some sheets of plain paper on your workbench.

Gluing the pieces

The front section (ie, where the display will be seen) can be identified by the four 5mm holes for the colon LEDs. Four more sections are glued to this to form an open box. These sections must be fitted with a specific orientation so before gluing them, put them together loosely to make sure you have the right pieces and understand the required orientations.

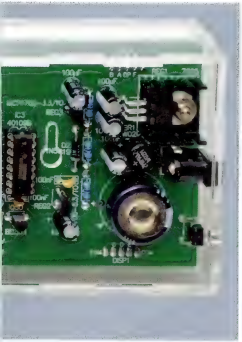
Start the assembly by gluing the top, bottom and side pieces to the front panel as shown in Fig.5. The front panel is rotationally symmetric so its orientation is not important but the other four pieces must be glued as shown. It's easiest to lay out the pieces around the front panel in the correct orientations before you start gluing any pieces, then start with one of the smaller left or right end panels.

When gluing these pieces, you will need to coat all the mating surfaces with a decent amount of adhesive to make sure the bonds are good. An example is shown in Fig.5 for gluing the top panel; the areas shaded red are where adhesive would need to be applied, assuming the left and right panels were already in place.

Note that you could coat just the surfaces of the panel being introduced to the assembly each time – you would need to apply adhesive to this which would mate with the red surfaces shown on the other pieces (which would have been difficult to depict from this angle).

Glue the first panel, then wait a few minutes for the adhesive to make a decent bond before moving on to one of the adjoining panels. Repeat until all four sides are in place, then quickly drop the rear panel into place (being careful not to get any glue on it) to check that everything is nice and square and nothing will foul the rear panel once the adhesive finishes curing.

The next step is to glue six small pieces to the rear panel, as shown in Fig.6. The trick is to use enough adhesive to give a good strong bond without the excess spreading out too much. You also need to be careful to make sure each piece is glued exactly perpendicular to the rear panel. Check that the four pieces which have holes



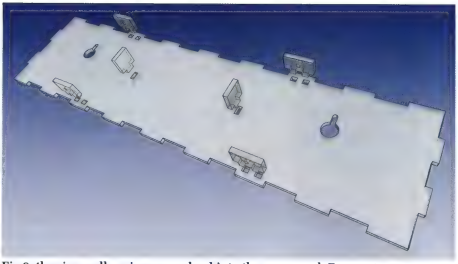


Fig.6: the six smaller pieces are glued into the rear panel. Be sure to use sufficient adhesive to form strong bonds. The four upper & lower pieces with holes are used to hold the back onto the case and by extension hold the case and whole assembly to the wall. The two smaller pieces glued in the middle press the PCB assembly up against the front of the case. The rear panel is symmetrical so the parts can be glued to either side as long as they're all on the same side.

in them are not angled out towards the edge of the panel as they must slot inside the top and bottom pieces of the case.

You can check this once the six pieces are in place and the adhesive has started to set; gently drop the rear panel into place and then remove to set.

It's best to leave the pieces overnight so the bonds achieve full strength. You can then introduce the PCB assembly into the case. Hold it at an angle and slide the DC socket and pushbutton into one side of the case, then rotate it until the 7-segment displays rest on the inside of the front panel.

The rear panel can then be attached using four 4GA self-tapping screws through the holes in the top and bottom that bite into the parts glued into the rear panel earlier. The basic idea is shown in Fig.7.

For desk use, fit a small rubber foot to each corner at the bottom. For wall mounting, two screws placed 200mm apart will fit into the slots on the back. The heads must be between 4mm and 9.5mm in diameter. Most small wood screws should fit; check before screwing them into the wall. Don't hang it until the adhesive has achieved full strength.

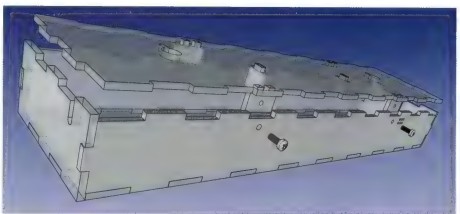


Fig.7: this shows the two halves of the case being put together; machine screws are shown however we recommend you use No.4 self-tapping screws. Be gentle when cutting the threads initially; if any of the smaller pieces break off during this process you will have to re-glue them and wait for the adhesive *to set again*.

LDR calibration

Once the unit is in place and powered up, calibrating the LDR is simple. Shine a bright light on the LDR for a few seconds (eg, a torch), then cover the unit up for a few seconds (eg, with a pillow case) to block out all light – or simply place it in a dark room and turn the lights off. The unit will automatically record the highest and lowest values read and adjust its calibration to suit.

GPS time acquisition

If there is no GPS module fitted, by default the unit will power up showing a flashing "12:00:00" display, waiting for the time and date to be set, as explained below. However, if a GPS unit is detected, the display will change to "GPS 00". As satellites are picked up, the number will be updated to show how many are "seen". If the unit has a 1PPS output, the decimal point after "GPS" will flash in time with it, until a GPS lock is acquired.

Once the unit has a GPS fix (latitute/longitude), the display will change to "GPS FI". It will then wait to receive valid date/time information, at which point the display will change to "GPS SE" as it searches for valid time zone data based on that information. Once the data is found, the display will change to show the local time.

If GPS fix is lost, the unit will fall back on its 32.768kHz crystal for timekeeping. After several minutes, the display will start pulsating (ie, varying in brightness over time) to indicate that it is no longer 100% accurate. If a GPS fix is re-acquired, the time is updated and it stops pulsating.

Setting up the IR remote

By default, the clock is set to re-

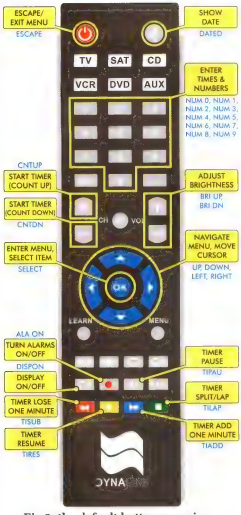


Fig.8: the default button mapping on the Altronics DynaLink A1012 remote control set to TV code 170. Other remotes can be used but you may have to program the button codes into the clock, as described in the text. If so, use this as a guide as to which buttons to map to what functions; the button function names displayed on the clock during set-up are shown in blue on this diagram.

spond to infrared remote commands from an Altronics/DynaLink A1012 learning remote on TV code 170. The default mapping is shown in Fig.8. The various functions indicated are described below.

We've chosen this remote because it's relatively inexpensive, easy to get, looks good and has all the buttons needed for this project. Having said that, just about any universal remote control can be used, including Jaycar's Cat. AR1719.

Whichever remote you use, it just needs to be set up to produce Philips RC5 or NEC-compatible infrared commands. To check this, point the remote at the clock and press the buttons. You may need to guess at some appropriate code settings first (eg, Philips TVs). Check the manual supplied with the remote.

If it's producing commands that the clock can receive, the last decimal point on the display will flash. While many different modes will produce some valid commands, you may need to try several different codes before you find one where all the buttons you need actually work. Refer to Fig.8 for guidance but note that the button mapping for your remote doesn't need to match exactly (ie, your remote may not have an identical button layout).

Once you have decided which remote to use and the setting to use it on, power up the clock and put it in IR set-up mode by holding down the buttons on either side of the clock simultaneously for several seconds. The display will show "IR SET". Release the buttons, then press the right-side button to continue.

The display will flash "NUM 0", indicating the button code that is to be set. Hold down the "0" button on your remote control for a second or two. It will then briefly show the remote code received and then the display will switch to flashing "NUM 1". Repeat this procedure for the remaining buttons. The codes corresponding to each button are shown in Fig.8.

If at any point you make a mistake, you can go back and reset the previous button code by pressing the left-hand pushbutton on the clock. If you don't want to assign a button to an IR code, press the righthand pushbutton to skip that one.

Once you have set all the codes, "IR FIN" will be shown. You can then press the right-hand button on the clock to go back to normal operation or the left button if you need to change a code first.

If necessary, buttons can be re-assigned later, using the "CHANGE" option in the "IR" menu. Menu operation is described below.

Setting the time & date

This is only necessary if you haven't fitted a GPS module. Press the OK button on the remote control and then press the down button until the display shows "SETDA". Press OK; the display will then show "010116" representing 1st January 2016 (assuming your date format is set to the default of DDMMYY). Use the keypad on the remote control to enter the correct date then press the select button.

You can then go back into the menu and select "SETTI". It will change to show "000000" representing midnight (HHMMSS). Check the current time, then enter what the time will be in a minute or two, in 24-hour notation using the keypad – but don't put in the last digit yet. Do that the instant that the reference clock matches the time entered.

This same procedure can be used to change the time or date at a later stage. Note that you can also use the up/down/left/right arrows to change the time and date, however it's easier to use the numeric buttons. If necessary, you can set the time and date without a remote; see the "Operating without a remote" section below.

If you want the clock to make daylight saving time (DST) changes automatically without a GPS module, you will also need to tell it which time zone you are in. This can be done before or after setting the time. Press the OK button on the remote control and then press the down button until the display shows "SETTZ". Press OK, then refer to Table 1 and choose the appropriate zone using the up/down. Press OK to confirm.

The default is "NONE" in which case no time zone calculations are done. If a time zone is selected which has no DST rules (as per Table 1), this will not have any obvious effect, except that changing to a different time zone will then change the time to suit that location. If a time zone with daylight savings rules is selected, those rules will be obeyed and the clock will automatically change the displayed time when appropriate.

It's possible to override the DST rules, should they change after this article is published, or if an error is found; we explain how to do that later in this article.

Showing the date

Once set, the clock normally displays the time. The date can be shown with a quick press of either button on the clock itself or by pressing the show date button (usually mute) on the remote control. It will be displayed for five seconds with decimal points separating the day/month/year, then the unit will switch back to time display.

Display brightness

Hold down the volume+ or volume– buttons on the remote control to vary

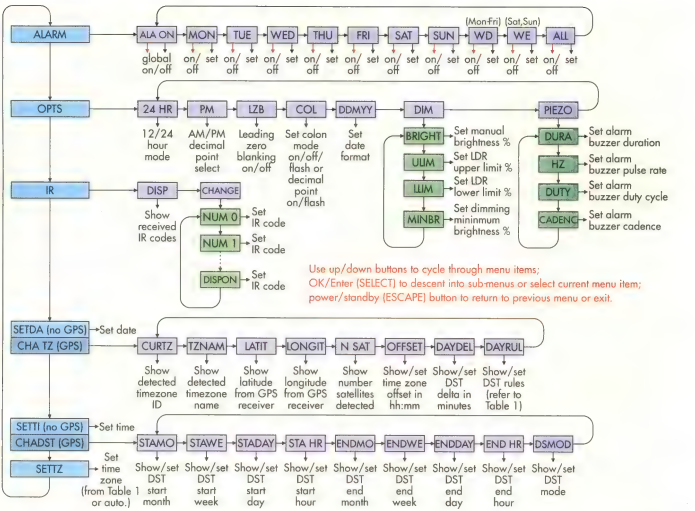


Fig.9: this shows the complete menu tree for the clock. The main menu is shown in blue on the left; two of the options vary depending on whether a GPS module has been detected or not. Sub-menu options are shown in mauve with their sub-menus shown in green. Pressing the OK/select button activates the function indicated for each menu item, allowing that parameter to be viewed or set. The escape (on/off) button goes out of the current menu and back to the parent, or in the case of the main menu, back to the regular time display.

the display brightness. Auto-dimming continues to operate, if configured. For example, if you've set the brightness to 50% and the auto-dim is at 50% then the overall display brightness will be 25% of maximum. You could omit auto-dimming and simply manually dim the display in this manner if you prefer.

Menu system

The time setting description above involved entering the menu to access the "SETDA", "SETTI" and "SETTZ" options. The full menu tree is shown in Fig.9. The top level menu, shown in the blue boxes at the left, is accessed by pressing the OK button on the remote (or via the pushbuttons, as described later). Up and down scroll through the list.

Each additional "level" of the menu is shown in a different colour and is accessed by pressing OK on its "parent" entry. Similarly, pressing the escape button (normally the power on/off button on the remote) will take you back up to the parent menu or back to the time display, if viewing the top level menu.

Below, we'll go through the remaining menu items and explain what they do, as well as detailing other clock functions accessed by different buttons on the remote.

Operating without a remote

The menu system can also be accessed without a remote, using the pushbuttons on the unit. Hold down the right pushbutton for at least one second and release it to enter the menu. Pressing the left button is then equivalent to the up button on the remote while pressing the right button is equivalent to down. These then let you scroll through the menus.

To escape from a menu, hold down the left button for at least one second and release. To select an item, hold down the right pushbutton for at least one second and release. When you get to a point where you need to enter a numeric value (eg, setting the time), short presses of each button will increment or decrement the currently selected digit.

Holding down the right button for at least one second will cycle to the next digit. Holding down the left button for at least one second will save changes and return to the previous menu item. Holding down both buttons together and then releasing will abort changing that value.

In this manner, you can operate

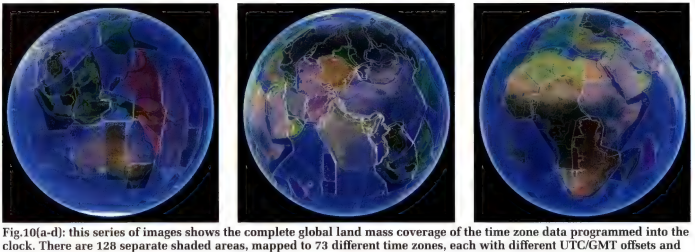


Fig.10(a-d): this series of images shows the complete global land mass coverage of the time zone data programmed into the clock. There are 128 separate shaded areas, mapped to 73 different time zones, each with different UTC/GMT offsets and daylight savings rules. You can download the data from our website and map it onto Google Earth to inspect or modify it. Note that many zones overlap which has been done to reduce the compressed size of the data set; see text for more details.

the menus without the remote. The buttons can also be used to show the date. However, note that many other functions are not available without a remote, such as timer modes and so on. Basically, the unit is designed to be used with a remote and the button functions are a fall-back, primarily intended for applications where it's used purely as a clock.

Setting the alarm

Normally, the right-most decimal point on the clock shows the global alarm status. If on, the alarm is set to go off at least once in the coming week. It's dim if there is no alarm set in the next 24 hours or bright if there is.

To set the alarm, enter the ALARM menu. You will see either "ALA ON" or "ALAOFF", indicating the global alarm on/off status. Press either OK or the record (ALA ON) button on the remote to toggle it. The ALA ON button will also work when the clock is showing the time, as a quick and easy way to enable or disable the alarm.

Cycle through the next seven menu entries to turn the alarm on or off for an individual day, or set the time for that day. The record button is used to toggle that day's on/off status while select can be pressed to set the alarm time, similarly to the way the clock's own time is set as described above.

You will also find menu entries for "WD" (weekdays), "WE" (weekend days) and "ALL". Changing the on/off status or time for any of these entries affects multiple alarms, ie, Monday-Friday for "WD", Saturday-Sunday for "WE" and Monday-Sunday for "ALL". They can still be individually changed after that. When finished setting alarm times, keep pressing on/off to exit the menus and return to the clock display.

Using the clock as a timer

The clock can count time upwards starting at zero (eg, to measure how long something takes) or downwards to zero (eg, to alert you when a certain amount of time has passed). It also has stopwatch type functions such as a lap counter. It counts with 1/100th second resolution for times less than one hour, 1/10th second resolution up to 10 hours, one second resolution for up to 100 hours and with further reduced resolution up to 1000 days.

Since infrared commands normally take the same amount of time to transmit, receive and decode, the timing should be pretty accurate, to within a few hundredths of a second. However, since there's no guarantee an infrared command will be received without corruption, you will need to hold down the button to start the timer reliably which could result in it sometimes being off by a fraction of a second.

There are three basic modes: count up with no limit, count up until a specific time is reached, or count down from a specific time to zero. When the limit is reached (either counting up or counting down), the piezo buzzer sounds, although this can be turned off if desired. Counting can be paused and the counter can have one minute added or subtracted while it's running.

Starting the timer

Press the channel+ button and the timer will start counting up from zero. You can tell the timer and not the clock is running since the colon LEDs switch off and the decimal points flash instead. Press the pause button to pause the timer; the display will freeze and flash. Press the play button to resume.

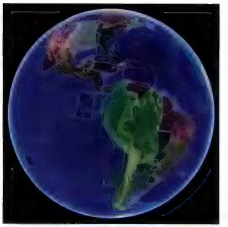
If you press the stop button, the display will freeze and flash but it will show the time for the last lap; ie, since the timer started for the first lap, or since the last time you pressed this button for subsequent laps. Press the play button to go back to the normal timer display. Pressing fast forward or rewind will add or subtract one minute from the displayed time.

Hold down the on/off button for a second or so to abort timer mode and go back to the normal clock display.

If you want to count up to a specific time, press one of the numeric buttons or up/down immediately after pressing channel+ (within a few seconds). Enter the time to count up to (in a similar manner to setting the time), with a maximum of 23 hours, 59 minutes and 59 seconds. Once you've entered the time, press select to start counting.

In this mode, the fast forward and rewind buttons change the target time by one minute; it will be briefly displayed when they are pressed, then it will go back to showing the timer. Also, when counting up to a target time, the last decimal point on the display indicates whether the buzzer will sound when the target is reached (by default, it's on). Press the record (alarm on/off) button on the remote to toggle it while in this mode.

Press the channel- (CNTDN) button to initiate counting down. The procedure is essentially identical to



counting up, except that you are always prompted to set the initial time, using the same method as described above. Essentially, this mode is identical to counting up towards a target time, except for the fact that the timer starts at the set time instead and counts down to zero.

Changing options

There are a number of options which can be changed through the "OPTS" menu. Once an option is displayed, use the OK button to change it. Numeric values can be changed using the up/down/left/right buttons or, in some cases, the numeric keypad on the remote. The options are:

(1) 12/24 hour time: the display shows either "12 HRS" or "24 HRS". The hours are shown as 01-12 in 12-hour mode or 00-23 in 24-hour mode.

(2) Leading zero blanking: the display shows either "LZB ON" or "LZBOFF". Press select to toggle between them. Applies only to the first digit on the display, ie, 3pm will be shown as "3:00:00" with leading zero blanking enabled or "03:00:00" with it disabled. This would normally be disabled in 24 hour mode but you can enable it if you wish.

(3) Hours/minutes/seconds separator in time display: there are five options: "COLFLA" (colons flash at 1Hz; default), "COL ON" (colons on permanently), "COLOFF" (colons off permanently), "DP ON", (decimal points on instead of colons) and "DP FLA" (decimal points flash instead).

(4) Dimming sub-menu: each entry allows you to set a value between 0% and 100%.

"BRIGHT" is the current manually displayed brightness setting. It also changes when the volume+ and volume- buttons are pressed.

"ULIM" is the percentage of ambient brightness where the display starts to dim automatically. For example, if set to the default of 75%, the display will be at full brightness between 75% and 100% ambient but will dim below 75% ambient. Set it to 0% to disable auto-dimming.

"LLIM" is the percentage of ambient brightness where the display reaches minimum brightness. It will not dim further as the ambient light level falls below. The default is 10%.

"MINBR" is the display brightness achieved at the lower ambient limit. Setting this to zero means the display will turn off entirely at the lower ambient limit. The default is 25%.

(5) Piezo buzzer sub-menu: this determines the sound the piezo makes when the alarm goes off or the timer expires.

The duration setting is from 0-60 seconds (0 seconds = off, default = 5s).

Hz indicates the frequency of the pulses from the piezo between 1 and 10Hz (default = 2Hz). Duty is the duty cycle from 1-100% (default = 50%). Each of these can be set by pressing select, then either up/down or using the numeric buttons to enter a value.

Cadence lets you enter three pairs of duration/pause values as a 6-digit number. The default is 100000 which gives an even series of pulses from the piezo at the selected frequency but, for example, a setting of 113200, in combination with a 2Hz frequency, would give a 0.5s beep, followed by a 0.5s pause, followed by a 1.5s beep, followed by a 1s pause, with this pattern repeating.

(6) Date format: this defaults to "DD-MYY" as is used in Australia. The other options are "MDDYY" or "YYMDD"; affects both date display and setting.

Changing infrared codes

The infrared menu, labelled "IR" has two sub-menu options: "DISP" and "CHANGE". If "DISP" is selected, the unit shows the Philips RC5 or NEC code for any button pressed on the remote. Press either pushbutton on the clock itself to exit this mode.

If "CHANGE" is selected, you can then select any of the remote button functions (as shown in Fig.8) using up and down and re-program it by pressing OK. The procedure is similar to that described in the initial setup above. Use the left pushbutton on the clock to abort and leave that code as it is or the right pushbutton to de-assign the existing infrared code for that button and disable it (until a new code is set).

Time zone/daylight saving data

As mentioned last month, the clock incorporates geographic data, time zone data and daylight savings data which allows it to determine the correct local time virtually anywhere on Earth's land mass with just the output of a GPS module. The geographic data is shown in Fig.10, plotted on top of the Earth's surface. Each coloured region represents a different time zone.

You may notice that many of the boundaries seem rather sloppy; this is done on purpose as borders defined with fewer points take up less flash memory. Basically, where two time zones meet (eg, at the border of two countries), we accurately define one border, which is often defined by a river or mountain range and thus has many wiggles – often requiring thousands of co-ordinates to define.

When we check whether your current location is within that time zone with the well-defined border, and the result is a negative, we don't need the border for the adjoining zone to be defined with such precision since we already know that if you are near the border, you are on the other side of it, by a process of exclusion.

As you can see, the data involved is substantial and it takes up about 150KB, even after a specially designed compression algorithm has been applied. If you're interested in more details, see the panel on pages 34 and 35 of the Feburary 2015 issue of SILICON CHIP.

Time zone data updates

We've made a substantial effort to provide up-to-date time zone geographical data and daylight savings rules in the firmware for the clock. However, the rules are very complex and vary drastically between different locations. They also change over time, so we decided there needed to be a way to keep the rules up-to-date, at least for the locations that constructors occupy.

As a result, the clock has the facility for you to change the rules for your current location. Updates are stored in the same section of flash memory as the clock options are kept and override the built-in rules.

There are three basic parameters for each location that can be changed: off-

Table 1: Time Zones & DST Rules

Display	Details	Offset	DST Rules
AU EAS	NSW, Vic, Tas	+1000	AUST
AU QLD	Queensland, PNG	+1000	-
AU SA	South Australia	+0930	AUST
AU NT	Northern Territory	+0930	-
AU WA	Western Australia	+0800	-
AU EUC	Eucla	+0845	AUST
AU LHI	Lord Howe Island	+1030	AUST (+30)
AU COC	Cocos Islands	+0630	-
AUMAC	Macquarie Island	+1100	-
NZ NZ	New Zealand	+1200	NZ
NZ CHA	Chatham Island	+1245	NZ
INTHAI	Indonesia/Thailand	+0700	-
JAPKOR	Japan/Korea/Palau	+0900	-
FIJI	Fiji	+1200	FIJI
USA HI	Hawaii	-1000	NTHAM
USA AK	Alaska	-0900	NTHAM
NA WE	USA/Canada West	-0800	NTHAM
NA MO	USA Mountain	-0700	NTHAM
NA AZ	Arizona	-0700	-
NA CEN	USA Central	-0600	NTHAM
NA EAS	USA Eastern	-0500	NTHAM
ASAMO	American Samoa	-1100	-
SA BOL	Bolivia, Eastern Quebec	-0400	-
CAN NL	Newfoundland	-0330	NTHAM
CAN NB	New Brunswick	-0400	NTHAM
PERU	Peru, Ecuador, etc	-0500	-
CAN SK	Saskatchewan	-0600	-
EUWES	Western Europe	+0100	EURO
EU IS	Iceland	+0000	-
EU UK	United Kingdom	+0000	EURO
EU EAS	Eastern Europe	+0200	EURO
EUMOS	Moscow	+0300	-
AS NKO	North Korea	+0830	-
AS BAN	Bangladesh	+0600	-
AS NEP	Nepal	+0545	-
RUWES	Western Russia	+0500	-
AFMOR	Morocco	+0000	MOROC
AF ALG	Algeria, Tunisia	+0100	-
AF LIB	Libya	+0200	-
AF EGY	Egypt	+0200	EGYPT
AFNAM	Namibia	+0100	NAMIB
AF AZO	Azores	-0100	EURO
AFMAU	Mauritius	+0400	-
IRAN	Iran	+0330	IRAN
AFGHAN	Afghanistan	+0430	-
ISRAEL	Israel	+0200	ISRAEL
GAZA S	Gaza Strip/West Bank	+0200	PALEST
JORLEB	Jordan, Lebanon	+0200	MIDEA
SA SEB	South-east Brazil	-0300	BRAZIL
SA NEB	North-east Brazil	-0300	-
SA PAR	Paraguay	-0400	PARAGU
BRAZIL	Rest of Brazil	-0400	BRAZIL
SA URA	Uruguay	-0300	URUGUA
SA VEN	Venezuela	-0430	-
MEXBJC	Baja California	-0800	MEXIC
MEX W	Western Mexico	-0700	MEXIC
MEX YU	Yucatan	-0500	MEXIC
MEX EA	Eastern Mexico	-0600	MEXIC
RU EAS	Eastern Russia	+1200	-
GEORGI	Georgia, Armenia	+0400	EURO
INDIAS	India, Sri Lanka	+0530	-
MONGO	Mongolia	+0800	MONGO
GRQAAN	Qaanaaq, Greenland	-0400	MEXIC
GREENL	Greenland	-0300	GRNLND
ATLSSI	S. Sandwich Islands	-0200	-
PA BAK	Baker Island	-1200	-
PASAM	Samoa	+1300	SAMOA
PA TON	Tonga, Tokelau	+1300	-
PA KIR	Kiribati, Line Islands	+1400	-
FR PON	French Polynesia	-1000	-
PAMAR	Marquesas Islands	-0930	-
PAGAM	Gambier Islands	-0900	-
PAPITC	Pitcairn Islands	-0800	-

set from UTC (in hours and minutes), daylight savings time shift (+0, +30 or +60 minutes) and daylight savings rules. The menus that provide these options also offer some information regarding the currently detected time zone and GPS module status.

There are 19 different sets of daylight savings rules, listed in Table 1 under "DST Rules". Table 1 also shows which set of rules is used by default in each location. The time zone menu allows you to change the setting for your current location to one of the other rules, including disabling daylight saving for a zone which previously used it, or enabling it for one which did not.

To change these options for your location, go into the "CHA TZ" menu (which appears when the unit has a GPS fix). The first five menu items simply show information; press OK to display that particular parameter and then escape (on/off) to go back to the menu.

Of the remaining three, "OFFSET" allows you to change the difference in hours and minutes between UTC/GMT and your time zone. This can be set anywhere from 22 hours before UTC to 22 hours after UTC in 15 minute intervals, although few locations use offsets of more than 12 hours from UTC.

"DAYDEL" allows you to select how much the time changes when daylight saving starts and ends. This will almost always be one hour (60 minutes) although there is one location, Lord Howe Island, which has a half hour (30 minute) DST delta. To disable daylight saving in your location, you can either set this to zero or change the DST rule to "NONE".

"DAYRUL" allows you to select the DST rules for your location. These rules define which hour of which day DST starts and ends in a given year.

Changing DST rules

Since these rules can also change, there is a separate menu called "CHADST" to change them. There are nine DST settings for each rule, represented by nine menu items, of which four define when it starts and four when it ends. The ninth determines how these are interpreted.

The most common mode, used by the vast majority of locations, is "HDWM" which stands for "hour, day, week of month".

For example, in Australia at the time of writing, daylight saving starts at 2am on the first Sunday of October and ends at 2am (3am DST) on the first Sunday of April.

So in this case, the mode is HWDM and the following rules are used:

STAMO: 10 OCT	FINMO: 04 APR
STAWE: 1ST	FINWE: 1ST
STADAY: SUN	FINDAY: SUN
STAHR: 2	FINHR: 2

(In this menu, the hour values always refer to the time before daylight saving is applied, hence FINHR is 2, not 3).

The following countries use different modes. Iran uses "EQUINO" where DST start/end dates are relative to the spring and autumn equinoxes. Brazil uses "NOCARN" which is identical to HDWM except that DST changes are delayed by one week if they fall during Carnaval. Similarly, "NORAM" delays DST changes if they fall during Ramadan and "NOROSH" delays DST changes if they fall during Rosh Hashana. SC

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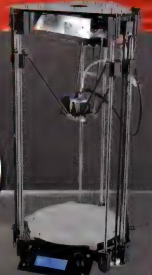

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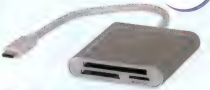

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$44.95

Corrector Speedo Module AA-0376

This module alters the speedometer signal up or down from 0% to 99% of the original signal. Input setup selection can be automatically selected and features a LED indicator.

- Power: 12VDC
- 63(L) x 46(W) x 25(H)mm

$99.95

In-Car Heads Up Display LA-9023

An easy-to-read and fully featured GPS speedometer that displays your car's speed on the windscreen as you drive. To operate, plug it into the 12 volt cigarette lighter socket and place on the dashboard.

- Includes 12V cigarette lighter lead
- 140(L) x 75(W) x 25(H)mm

Errors may occur due to environmental conditions.

$59.95

Automotive Multi-Function Circuit Tester WITH LCD QM-1494

For 12V or 24V electrical systems. Test the voltage and polarity of a circuit or whether it's short or open, check continuity, locate cylinders which are misfiring, measure frequency of ignition pulses, test solenoids, lights and more.

- 240(L) x 78(H) x 40(W)mm

$69.95

OBD2 Bluetooth® 4.0 Engine Code Reader PP-2145

Modern car engines are controlled by computers which regulate engine performance. Reading data from these computers pinpoints where problems may lie in car performance. Find this information with the OBD2 Bluetooth® engine code reader which will immediately interpret the information in the engine control unit.

Apps available from App Store and Google® Play store.

Digital Tachometer QM-1448

This unit features a large LCD display, laser pointer, low battery indicator, and memory recall and a DC socket for mains power (5VDC at 50mA). Supplied with carry case and 600mm reflective tape marks.

- 50mm to 500mm detecting distance
- 4 x AA batteries included
- 72(W) x 160(H) x 37(D)mm

$79.95

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON THESE CONTROL LOCKS

$12.95

DOUBLE POINTS

Slave Door Lock Actuators LR-8813

Used on passenger doors. Durable, waterproof, dustproof and supplied with universal mounting hardware. Wiring not included.

- Input voltage: 9 - 16VDC

ALSO AVAILABLE: MASTER DOOR LOCK ACTUATOR LR-8815 **$14.95**

$39.95

DOUBLE POINTS

Electric Car Boot / Hatch Release LR-8834

Solenoid comes with mounting bracket, wiring loom (fuse included), dash mount push button switch and installation instructions.

- Solenoid Unit (inc bracket): 95(L) x 43(D) x 58(H)mm
- Switch (on L bracket): 50(H) x 44(W) x 40(D)mm.

$39.95

DOUBLE POINTS

4 Door Power Lock Kit LR-8812

Add that touch of luxury to your car with this low cost 4 door central locking kit, so when you unlock the drivers door the other three doors will also unlock. A superior quality locking kit.

Supplied with 1 master and 3 slave actuators, control relay, hardware and wiring loom.

$49.95

DOUBLE POINTS

Remote Controlled Car Central Locking System LR-8839

Upgrade to a remote keyless entry with this system. Easy to install and comes with two remote key fobs.

Includes master actuator, wiring and two remote controls.

IN-CAR ENTERTAINMENT

FROM $79.95

CS-2402

Kevlar Coaxial Speakers
WITH SILK DOME TWEETERS

These awarded speakers provide a clean, crisp, natural and smooth balance sound. Now at a more competitive price, these speakers are great value for money. Sold as a pair. Includes 3 year warranty.

4" 40WRMS CS-2400 **$79.95**
5" 50WRMS CS-2401 **$99.95**
6.5" 75WRMS CS-2402 **$129**
6 X 9" 75WRMS CS-2403 **$149**

$149

Under Seat Active 8" Subwoofer

CS-2286

MOSFET output stage for low distortion and noise. The compact size means it will fit under a seat and is robust enough to take some knocks. Ideal for utes, convertibles and trucks.

- 55WRMS power output
- 40 - 280Hz @ 12dB/octave
- 360(L) x 250(W) x 80(H)

$229

In-Dash Multimedia Player
WITH USB AND BLUETOOTH® QM-3788

A solid all-round performer, that plays various multimedia formats, features the latest in file sharing with Bluetooth®, front panel SD card slot, USB port and aux-in.

- Supports MP3, JPEG and WMA files.
- AM/FM radio with 18 x AM and 12 x FM presets
- Plays DVDs, VCDs and CDs.
- 4 channels x 20WRMS output (40WRMS max)

NEW

$279

9" LCD Monitor
WITH 4 CHANNEL DVR QM-3872

Ideal for trucks, buses, caravans and other heavy-duty mobile installation, connects up to 4 cameras and is able to record all 4 channels with 12/24V mobile DVR.

- Records onto an SD card (sold separately).
- Supplied with power cable, remote control and user manual.
- 240(W) x 163(H) x 26(D) mm

$9.95 ea

Ground Loop Noise Isolators

Used to eliminate ground loop hums and noises in audio installations. Suitable for use with laptops, mp3 players, iPods, in-car DVD players, etc. 2 Channel.

RCA STEREO FLYEADS AA-3084 **$9.95**
3.5MM STEREO FLYLEADS AA-3086 **$9.95**

$14.95

Speaker to Line Level Converter

AA-0482

Converts high level speaker signals back down to low level or <1volt so you can safely connect your amps without damaging them or other speakers. RCA socket out (stereo).

FROM $14.95

Sound Deadeners

Self-adhesive and easily moulded.
Provides acoustic isolation and insulation for roof, firewall, floor, quarter panels, doors and under bonnets. 330mm wide.

FOAM ABSORBER 660MM AX-3662 **$14.95**
BUTYL DEADENER 900MM AX-3687 **$29.95**
BUTYL/FOAM COMBO 660MM AX-3689 **$29.95**

$64.95

Car Amplifier Wiring Kit AA-0442

A complete 8G wiring kit for installing an amplifier into your vehicle.

Kit includes 6m x 8G power cables, 3m x 16G speaker wire, 5.2m stereo RCA interconnect, 5.2m 18Ga remote wire, gold plated fuse holder, 40A fuse Loom tubing, gold plated crimp connectors, grommets, cable ties & self-tapping screws

IN-CAR CONNECTIVITY - DOUBLE POINTS FOR NERD PERKS CARD HOLDERS

FROM $5.95

PS-2096

Merit Connectors

Commonly used in automotive power connections.

UNFUSED PLUG 15A. PP-2090 **$5.95**

PLUG 8A. Cigarette lighter adaptor. PP-2094 **$6.95**

DOUBLE POINTS

PANEL SOCKET 15A with cover. PS-2092 **$9.95**

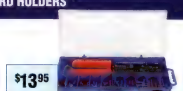
IN-LINE SOCKET 15A with cover. PS-2096 **$6.95**

FROM $6.95

DOUBLE POINTS

5VDC USB Car Chargers

1A USB MP-3661 **$6.95**
2.1A DUAL USB MP-3663 **$9.95**
4.8A DUAL USB MP-3667 **$15.95**

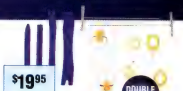


$13.95

DOUBLE POINTS

Automotive Crimp Tool
WITH CONNECTORS TH-1848

This excellent tool comes with 80 of the most popular automotive connectors. The tool will cut & strip wire, crimp connectors and also cut a range of metric bolts.



$19.95

DOUBLE POINTS

12 Piece Audio and Interior Removal Kit TH-2339

This set of pry bars allow you to remove all the panels including those upholstery clips. They are made of ABS plastic and are extremely sturdy. Designed to suit any car model.

DOUBLE POINTS

FROM $3.95

SZ-2042

Blade Fuse Holders

These fuse holders accept ordinary blade fuses and have an integrated lamp that lights up when the fuse blows, making it easy to find the offending fuse.

30A STANDARD Failure lamp. SZ-2042 **$4.95**
30A MINI Failure lamp. SZ-2043 **$4.95**
30A INLINE STACKABLE SZ-2045 **$3.95**
30A WATERPROOF Long transparent cover. SZ-2047 **$6.95**

DOUBLE POINTS

FROM $7.95

Waterproof Plug & Socket Set

Features sealed interlocking parts and individual grommet seals on each wire. All 20A rated.

2-WAY PP-2110 **$7.95**
3-WAY PP-2112 **$10.95**
4-WAY PP-2114 **$16.95**
6-WAY PP-2116 **$19.95**

ALSO AVAILABLE: WATERPROOF DEUTSCH
2-WAY CONNECTOR SET PP-2150 **$6.95**

DOUBLE POINTS

FROM $12.95

SZ-2002

Fuse Boxes

Features a common supply rail and includes a removable protective cover

AUTOMOTIVE FUSE BOX - 6 BLADES SZ-2002 **$12.95**

10 WAY BLADE FUSE BLOCK With LED Indicators. SZ-2008 **$19.95**

DOUBLE POINTS

FROM $19.95

Modular Design Negative Bus Bar and Blade Fuse Holder

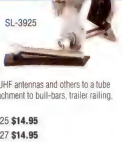
These fuse blocks come with blown fuse indication LEDs and transparent cover with recessed areas for label stickers.

MODULAR DESIGN NEGATIVE BUS BAR SZ-2011 **$19.95**

MODULAR DESIGN BLADE FUSE BLOCK SZ-2013 **$34.95**

See terms & conditions on page 8.

CAR LIGHTING - EXTERIOR



FROM $14.95

SL-3925

Universal Bullbar Mounting Brackets

Mount driving lights, spotlights, UHF antennas and others to a tube frame. Allows for much easier attachment to bull-bars, trailer railing, ute roll-bars or even a roof rack.

25-38MM DIAMETER SL-3925 **$14.95**
40-52MM DIAMETER SL-3927 **$14.95**
70-80MM DIAMETER SL-3929 **$19.95**

NEW

$79.95

2,500 Lumens Single Row LED Worklight SL-3975

Just hook it up to your 12V or 24V battery system. Excellent in 4WD, marine, caravan, mining, or any other harsh environment application. Stainless steel mounting hardware included.

- Flood beam output.
- 92m beam.
- 140(L) x 45(H) x 71(D)mm

FROM $229

Solid LED Single Row Light Bars

The single row design provides a lower profile compared to dual row, and are much more efficient.

COMBINATION BEAM:
7,200 LUMENS 13" SL-3985 **$229**
14,400 LUMENS 24" SL-3986 **$399**
21,600 LUMENS 35.6" SL-3988 **$599**
SPOT BEAM:
14,400 LUMENS 24" SL-3987 **$399**
21,600 LUMENS 35" SL-3989 **$599**

NEW

$79.95 ea

720 Lumens 2.5" Vehicle Lights

Cost effective waterproof, dustproof and shockproof lights powered by Cree® suited to the rough demands of 4WD or marine lighting applications. 10W. Sold as a pair.

FLOOD SL-3938
SPOT SL-3939

NEW

$119.ea

1,450 Lumens LED Vehicle lights

Extremely bright and affordable. Housed in die cast aluminium alloy with tough polycarbonate lens refractors. A stainless steel mounting bracket is included for each globe. Sold as a pair.

SPOT SL-3934
FLOOD SL-3936

$149.ea

3,486 Lumens 4.5" Solid Driving LED Lights

IP68 waterproof and shockproof rated. Draw a measly 34W, works off 12VDC or 24VDC and can handle pretty extreme temperatures without fuss. Stainless steel mounting hardware included.

- Sold individually

FLOODLIGHT SL-3918
SPOTLIGHT SL-3919

NEW

$369.ea

10,000 Lumens 8" LED Driving Lights

- Waterproof (IP68) rated
- Stainless steel mounting hardware included
- Sold individually

DRIVING SL-3990
SPOT SL-3992

4WD LIGHT BUNDLE

VALUED OVER $578

BUNDLE DEAL INCLUDES:
2 X 6,300 LUMENS 6.5" SOLID LED DRIVING LIGHTS SL-3920 **$249**
1 X WIRE STRIPPER TH-1824 **$16.95**
1 X LENS COVER SET SL-3923 **$29.95**
1 X UNIVERSAL RELAY WIRING KIT With switch. SY-4079 **$33.95**

BUNDLE $499

SAVE OVER $79

INTERIOR CAR LIGHTING

LED Globes

This range of common automotive and general use LED globes are also compatible with modern CANbus systems.

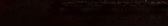
- 12VDC
- 6x5730 LEDs
- Non-polarity circuit
- 150 Lumens
- 28(H) x 12(Dia)mm

T10 WEDGE ZD-0730
E10 SCREW ZD-0732
BA9S BAYONET ZD-0734

ZD-0734

$14.95 ea

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON THESE LIGHTS



FROM $149

DOUBLE POINTS

Headlamp LED Kits

POWERED BY CREE®

Each kit contains 2 x LED modules, 2 x controller assemblies, and all the wiring is pre-terminated to appropriate connectors to make installation as quick and easy as possible.

H7 LO 3000 LUMENS 30W SL-3522 **$149**
H4 HI/LO 3800 LUMENS 40W SL-3524 **$169**

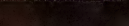
DOUBLE POINTS

$39.95

12V LED Trailer Lights ZD-0720

"All-in-one" solution measuring only 100mm x 90mm, providing all the legal illumination needs of a caravan, boat trailer, camping trailer etc., (Stop, Tail, Turn and number plate illumination, along with a red reflector panel). The housing is submersible which is perfect for boat trailers, and each light is fitted with a connector and matching 200mm wiring harness to allow for easy installation. Sold as a pair.

- 200mm wiring lead with plug
- 100(W) x 90(H)mm



DOUBLE POINTS

$69.95

12V LED Trailer Lights Kit ZD-0722

These trailer lights are an "all-in-one" solution. Not affected by shock and vibration. LEDs last over 50,000 hours, use a fraction of the power, and are more visible to other road users. Sold as a pair.

Kit includes 2x trailer lights, with a pre-made 7m trailer cable with 7pin flat trailer connector

- ADR Approved
- Screw stud mount.
- 100(W) x 90(H)mm (each)

HOT PRICE TORCHES - 20% OFF*

*Valid with purchase of ST-3370, ST-3372, ST-3374, ST-3357, ST-3358 and ST-3356

FROM $7.95 ST-3274 SAVE 20%

LED Worklights

Powered by 3 x AAA batteries (included).

100 LUMENS COMPACT WORKLIGHT
ST-3270 **WAS $9.95 NOW $7.95 SAVE $2**

180 LUMENS, 3W COB AUTO WORKLIGHT
ST-3272 **WAS $14.95 NOW $11.95 SAVE $3**

250 LUMENS, 3W COB + 0.5W LED
ST-3274 **WAS $39.95 NOW $31.95 SAVE $8**

NOW $23.95 SAVE 20%

3-in-1 LED Torch

ST-3357 **WAS $29.95**
Features 3 bright white LEDs, an AM/FM radio, as well as a personal alarm to attract attention. Charge by turning the dynamo handle or with a micro-B USB cable.

- 136(L) x 48(W) x 34(H)mm

NOW $35.95 SAVE 20%

LED Torch/Radio/ USB Charger Dynamo

WITH BUILT-IN SOLAR PANEL
ST-3358 **WAS $44.95**
Charge the internal battery using a USB power source; built-in solar panel; or hand crank dynamo.

- 135(L) x 64(W) x 40(D)mm

NOW $47.95 SAVE 20%

Dynamo Multifunction Torch/Music Player/Radio/Phone Charger

ST-3356 **WAS $59.95**
Crank the dynamo handle for power and you have a torch, music player, AM/FM radio and Smartphone charger! 4 red LEDs act as an emergency beacon/siren.

- 190(L) x 125(W) x 90(D)mm

Limited stock. Not available online.

TORCHES - DOUBLE POINTS FOR NERD PERKS CARD HOLDERS

DOUBLE POINTS

$29.95

370 Lumens USB Rechargeable LED Torch ST-3490

A great little LED torch with handy USB charging.

- 4 hours (at 100%) Burn time
- Light modes: high, low, dimmable and flash
- 150(L) x 37(Dia.)mm

DOUBLE POINTS

$54.95

700 Lumens Rechargeable LED Torch ST-3485

High powered with a fully adjustable beam spread. Black with tactical switch for mode adjustment.

- Battery, charger and mains power supply included.
- 1 x 18650 Li-ion battery included
- 128(L) x 38(Dia.)mm

DOUBLE POINTS

$89.95

1,200 Lumens Head and Bike Torch Kit ST-3467

A brilliant white light for the last word in bike safety.

- Handlebars and headstrap mount
- Water resistant
- Rechargeable with mains charger included.
- 54mm(L) x 42mm(Dia.)

$99.95 DOUBLE POINTS

700 Lumens Waterproof Spotlight ST-3313

Ideal for adventures or roadside emergencies. XM-L2 Cree® white LEDs, rechargeable.

- 4 Lighting modes
- Buoyant & submersible up to 1m
- IP67 Waterproof & Dustproof
- 180(H) x 146(L) x 75(Dia.)mm

VERSATILE LIGHTS - DOUBLE POINTS FOR NERD PERKS CARD HOLDERS

Rechargeable LED Work Lights

They include rechargeable batteries so you can keep one in the car or caravan to shine a huge amount of light on engine, or campsite but can also be mains powered if needed.

FLOODLIGHT 10W 500 lumens.
SL-2887 **$49.95**

FLOODLIGHT 30W 1,500 lumens.
SL-2889 **$99.95**

WORK LIGHT 30W 1,500 lumens.
SL-2886 **$149**

SL-2887 Limited stock
Not available online.

DOUBLE POINTS

FROM $49.95

SL-2886

1,200 Lumens Rechargeable LED Worklight

WITH TRIPOD SL-3240

- Extends into a light on a tripod up to 1.8m
- 2x Cree® XML T6 LEDs on a tilting head
- Includes carry bag to fit the light, cigarette charger and mains chargers.
- 800(L) x 120(Dia.)mm

DOUBLE POINTS

$199

DOUBLE POINTS

Solar Rechargeable LED Worklight WITH USB SL-2792

- 5W COB LED
- 300 Lumens
- 3 hours Burn time
- Solar or mains rechargeable
- IP54 Weatherproof rating
- 245(H) x 170(W) x 250(D)mm

$79.95

DOUBLE POINTS

SL-2877

FROM $34.95

240VAC LED Worklights

High brightness, long life LED work lights suitable with extremely low wattage and with an energy efficiency greater than 90% they are also environmentally friendly. IP65 rating.

500 LUMENS 10W SL-2876 **$34.95**
1,500 LUMENS 30W SL-2877 **$79.95**

500 Lumens Rechargeable LED Worklight SL-2809

Features a built-in rechargeable battery so you don't need to be tied to a mains power source, and a dimmable LED so you can adjust the brightness depending on your application.

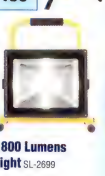
- 3 hours burn time
- IP65 water resistant rating
- 10W power consumption
- 109(L) x 115(W) x 87(D)mm

DOUBLE POINTS

$79.95

DOUBLE POINTS

$129



240VAC 3,800 Lumens LED Worklight SL-2699

- IP65 rating
- 50W power consumption
- 285(L) x 230(H) x 145(D)mm

DOUBLE POINTS

$179

Solar Rechargeable Motion Sensing LED Flood Light SL-2808

- 3W solar panel power with 3m cable
- Polycrystalline solar panel type
- 266(L) x 130(W) x 14(D)mm solar panel
- 500 Lumens 10W light power
- 3 hours light working time
- 175(H) x 145(W) x 53(D)mm light

ALL YOU NEED FOR YOUR OUTDOOR ADVENTURES

UHF ACCESSORIES

$329

Tradies Pack - UHF CB Radio DC-1076

Pack includes 2 x 3W 80ch waterproof floating UHF transceivers, 2 x mini speakers/microphones, 2 x 12V cigarette lighter charger leads, 2 x V/OX headset and microphones, 1 x dock with mains plugpack.

- 400 x 280 x 100mm

FREE SPEAKER MICROPHONE FOR HERD PERKS CARD HOLDERS* DC-1066

DC-1066 VALUED AT $24.95

UHF Transceiver DC-1065

Remarkable range and clarity. With a powerful 5W output you'll be able to communicate far beyond consumer grade models.

- 3km/20km range
- 80 channels
- 130(L) x 60(W) x 35(D)mm

$159

Ground Plane Independant Antenna Kit DC-3071 WAS $119

High gain mobile antenna suitable for cars, RV's and trucks. Kit includes stainless spring & elevated feed base, 6.5db & 3dB factory tuned antennas, 5m RG58 lead with FME socket and PL259 adaptor, as well as buil bar and 'L' guard mounts.

$99

SAVE $20

120W OUTDOOR FOLD-UP SOLAR POWER PACKAGE ZM-9320

VALUED OVER $1127

For portable applications, including camping, to power a 12V fridge/freezer, LED lighting, etc. Position the folding solar panel to get the most sunlight.

BUNDLE DEAL INCLUDES:

120W PORTABLE FOLDING SOLAR PANEL ZM-9134 **$499**

PORTABLE BATTERY BOX Includes power accesories. HB-8500 **$99.95**

12V 100AH DEEP CYCLE GEL BATTERY SB-1695 **$429**

FLEXIBLE LED STRIP LIGHT Hook & loop case and carry bag. ST-3950 **$99.95**

ALSO AVAILABLE:

180W OUTDOOR FOLD-UP SOLAR PANEL ZM-9322 **$1299**

BUNDLE $999

SAVE OVER $128

FROM $49.95

MB-3606

Multi-Stage Battery Chargers

Suitable for charging and maintenance.

3-STAGE 6/12V 750mA. MB-3603 **$49.95**

5-STAGE 12V (0.8A / 3.8A, IP65 rated). MB-3604 **$89.95**

5-STAGE 12/24V Switchmode 7A. MB-3606 **$169**

Power Banks

These foldable pocket size solar panels with a built-in lithium battery allows charging your gadgets wherever and wherever.

4000mAh MB-3722 **$64.95**

6000mAh MB-3720 **$119**

10,400mAh WATERPROOF MB-3728 **$99.95**

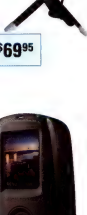
FROM $64.95

MB-3720

Hand-held Anemometer WITH TRIPOD STAND QM-1644

Measures wind-chill, air temperature, displays current, maximum and average wind speed. Wind speed (from 0.64 to 107.82 km/h) is measured in: feet/min, MPH, km/h, metres/sec or knots. Includes a Beaufort scale display. Can be hand held or fixed to stand supplied.

- 115(H) x 45(W) x 16(D)mm without stand.



ALSO AVAILABLE:

WIND SPEED METER/ THERMOMETER (ANEMOMETER) QM-1646 **$129**

$69.95

FREE EMERGENCY KIT FOR NERD PERKS CARD HOLDERS* ST-3267

ST-3267 VALUED AT $24.95

FROM $119

12VDC Air Compressors

Powerful and great for a variety of outdoor activities and emergency situations such as pumping flat car, 4x4, truck tyres, inflatable boats, air beds, etc.

MEGA-FLOW AIR COMPRESSOR 180L/MIN MC-7200 **$199**

HIGH-FLOW AIR COMPRESSOR 72L/MIN MC-7202 **$119**

HDR Time Lapse Professional Video Recorder QC-8038

Create stunning time lapse videos with the advanced High Dynamic Range image sensor. HDR is a technique used in imaging and photography to reproduce a greater dynamic range of luminosity than is possible with standard digital imaging or photographic techniques. It captures excellent videos/images in harsh or low light (without wash out). The 1.44 LCD viewfinder allows for easy setup of the perfect angle. A CS mount lens is included for interchanging with virtually any other CS mount lens. (results may vary). A 4GB SD card is included (capture up to 30,000 images).

ALSO AVAILABLE:

WEATHERPROOF HOUSING QC-8040 **$79.95**

STOP MOTION SHUTTER LINE QC-8033 **$19.95**

$489

OUTDOOR BUNDLE

BUNDLE OFFER

BUY ALL 4 FOR $99.80

SAVE $23

$17.95

Multi Function Survival Knife TH-1925

- 420 Grade stainless steel for maximum durability.
- Blade features straight and serrated edges
- Built-in LED lighter
- Belt cutter

Age restriction laws apply in some Australian states.

$9.95

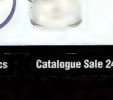
SAVE $8

18 Piece Survival Water Bottle Kit ST-3269 WAS $17.95

Kit contains 945ml BPA free water bottle, reusable rain poncho with hood, emergency survival blanket, 18 piece first aid kit (alcohol pads, antiseptic cleaning pads, anti mosquito towelettes, sticky plasters and small bandages), 2hr light-stick, whistle, waterproof matches, and carabiner clip.

3W Head Torch ST-3279

- Three modes of operation - high, low and strobe
- 180/80 lumens
- 8hrs burn time
- Water resistant
- Requires 3 x AAA batteries



$19.95

Rechargeable Handheld CB WITH TORCH DC-1009

- Sold as a pair.
- 0.5W 80 channels
- With LED torch built in to it
- Charging cradle included
- Up to 3km range
- Up to 30 hours battery

$74.95

DIY ROBOT KITS

DOUBLE POINTS

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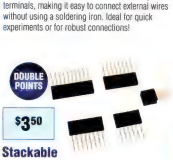

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PRODUCT SHOWCASE

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A 3G modem provides wireless access to the internet over the mobile network, allowing remote control via the free computer or smartphone app . This shows the touchscreen as if you were standing next to it, allowing you to start/stop the pump and view operations and alarms.

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PO Box 2191, Seaford BC, VIC 3198
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To celebrate this exciting milestone, the company will be recognizing key customers in regions all over the world who have partnered with Digi-Key to make their business grow.

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Multiple on-board sensors (temperature, humidity and acceleration) and buzzer, LEDs, I/O-functionality and a pushbutton enable integration into a variety of custom (M2M) applications (eg, Internet of Things and smart wearable electronics).

Size is just 50 x 15mm and weight 3.4g. With a battery life of more than 10 years, the module offers numerous OEM integration possibilities.

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According to crash data for the Sydney region, 26% of crashes are rear-end and almost half (42%) result in injury. The QuickBrake reduces the risk of a rear-end collision by giving a much earlier "brake lights warning" to following drivers than any normal car. It does this by switching on the brake lights even before you have a chance to depress the brake pedal.

QuickBrake senses when you quickly lift your foot off the throttle (accelerator) pedal and then instantly switches on the brake lights, well before you have had a chance to depress the brake pedal. It does this by sensing the difference between normal throttle movements and the quick lift-off when you are about to suddenly brake. The sensing is done by monitoring the voltage from the throttle position sensor (TPS) or a Manifold Absolute Pressure (MAP) sensor.

Fast pedal movements will show up as an abrupt voltage change from the sensor. Whenever these fast voltage changes are detected, QuickBrake will switch on the brake lights.

Before we continue we should point out that the QuickBrake will not work if you are in cruise control since the throttle pedal is not in use. And it may not be useful in cars with manual gearboxes since it could be confused by the throttle pedal movements when you are accelerating rapidly and changing the gears with gusto. That's because there is no difference in the sensor voltage changes between lifting your foot off from the throttle during gear changes to those when you are about to brake suddenly.

Finally, if you are coasting on a "trailing throttle", there will be no signal to the QuickBrake if you suddenly need to apply the brakes.

So why do you need QuickBrake? You might think that you can move your foot very quickly between the throttle and brake pedals in a panic stop situation but the reality is very different. It can depend on a whole range of factors: your age, fitness, whether you are alert or sleep-deprived, the shoes you are wearing (thongs, high heels?), the closeness and height difference of the pedals, pedal offset and so on.

The reality is that the typical time to move your foot from throttle to brake ranges from 250-750 milliseconds! If you don't believe those figures, have a look at www.researchgate.net/publication/233039156_Brake_Reaction_Times_and_Driver_Behavior_Analysis

Of course, that time to move your foot is on top of the time it takes to re-

The parts all mount on a 105.5 x 60mm PCB. This can be clipped into a UB3 utility box and fitted under the dashboard or in the boot.

act to the fact that you actually need to apply the brakes! That can be as long as 250-500 milliseconds (provided you are not affected by tiredness, alcohol, fatigue etc). Unfortunately, QuickBrake cannot do anything about your initial reaction time and you need to give yourself a good margin for error by making sure you keep a"3-second gap" from the vehicle ahead.

So QuickBrake's function is to drastically eliminate the time from throttle lift-off to brake light illumination, to give following drivers a much earlier warning that your brakes are about to be applied. How much earlier? QuickBrake's response time from throttle lift-off is typically only 10 milliseconds and that is mainly the response of the switching relay.

So if the typical driver's pedal response time is 0.5 seconds, then QuickBrake will react 490ms earlier; virtually instantaneously! At a speed of 100km/h that is a distance of almost 14 metres! That gap could be the difference between a sudden stop for the following driver and a serious accident involving major injuries and severe vehicle damage.

More to the story

So far we have talked about how fast QuickBrake can apply power to the stop lights. But how long does it take the stop lights to come on when they are powered up? And what is the difference in response between LEDs and the 5W filament lamps typically used for the CHMSL (centre high mount stop light) and 21W main brake lights?

As most readers would be aware, filament lamps are notoriously slow to light up. Standard 21W filament bulbs can take somewhere between 200-230ms to fully light up after power is applied to them. CHMSLs are faster, due to their smaller filaments, at around 60-80ms to fully light.

So to give you a further safety margin, we strongly recommend changing the brake lamps to LEDs. If that seems too hard, you can still benefit by changing the lamps in your car's CHMSL to LEDs and thereby provide extra warning time for the motorist behind you when braking.

There is a drawback to fitting LEDs and that is because your car's body computer may sense the higher resistance of the LED lamp assembly as an open-circuit filament. We have taken care of this problem in the QuickBrake circuit, as will be described later.

Presentation

QuickBrake uses a small PCB that can be mounted inside a plastic case. It needs to be connected to a 12V ignition switched supply, the brake lights and to a TPS or MAP (manifold air pressure) sensor. You would need to fit a MAP sensor to the engine's manifold vacuum connections in an older vehicle, if it does not does not have a throttle position sensor (TPS).

Usually, the TPS voltage is high (say, 3-5V) depending on the throttle opening and drops to zero when the throttle is closed. Similarly, the MAP sensor's voltage will be high when the throttle is wide open and low when the engine is idling or the throttle is closed.

Circuit description

Fig.1 shows the circuit. It uses two dual op amps (IC1 & IC2) and a 7555 timer (IC3). The circuit is designed to detect the rapid change of voltage from the TPS or MAP sensor and then switch on a relay which is connected in parallel with the car's brake pedal pressure switch. The QuickBrake relay then stays on for a period of time before it is switched off.

The dual op amps are an LMC6482-AIN (IC1) and an LM358 (IC2) and these run from a +5V supply. The DC voltage from the MAP sensor or TPS is fed via a 1MΩ resistor with 100 nF low-pass filter capacitor to the non-inverting input of IC1a. This operates as a unity gain buffer. Its pin 1 output drives a differentiator comprising a 100nF capacitor, 1MΩ trimpot VR1 and a series-connected 100kΩ resistor.

The differentiator acts as a high-pass filter, letting fast-changing signals through but blocking slowly-changing signals. This is exactly what we want in order to sense the abrupt change as a person lifts off the throttle prior to braking.

The differentiator is connected to a 2.5V reference which is derived from the 5V rail with a voltage divider using 1kΩ divider resistors, bypassed with a 100µF capacitor. With no signal passing through the 100nF differentiator capacitor, the output voltage on the VR1 side of the capacitor sits at +2.5V.

Depending on how the vehicle is being driven, the MAP or TPS signal will either be steady or decreasing or increasing in voltage. Exactly how much signal passes through the 100nF differentiator capacitor is dependent on the rate of voltage change and the setting of trimpot VR1. VR1 sets the time-constant of the differentiator so high resistance settings for VR1 will mean that the circuit responds to more slowly changing signals from the TPS or MAP sensor.

The differentiator output is buffered using op amp IC1b and it provides the high-to-low (H/L) output. IC2a is wired as an inverting amplifier and it inverts the output from IC1b. This provides the low-to-high (L/H) output.

Jumper link JP1 then selects the output of IC1b or IC2a. This allows triggering on a falling (H/L) or rising (L/H) input signal. The selected signal is applied to IC2b, a Schmitt trigger stage. IC2b has its inverting input connected to a 2.27V reference derived using 12kΩ and 10kΩ resistors connected across the 5V supply. The non-inverting input is connected to JP1 via a 10kΩ resistor. A 1MΩ resistor connects between the non-inverting input and IC2b's output.

Parts List

1 double-sided PCB, code 05102161, 105.5 x 60mm
1 UB3 plastic utility box, 130 x 68 x 44mm
1 12V DC DPDT PCB-mount relay (Jaycar SY-4052 [5A], Altronics S4190D [8A], S4270A [8A]) (RELAY1)
1 set of Quick Splice connectors (Jaycar HP-1206 or similar)
3 2-way PCB-mount screw terminals, 5.08mm spacing (CON1,CON3)
2 3-way PCB-mount screw terminals, 5.08mm spacing (CON2,CON3)
1 3-way pin header, 2.54mm pin spacing (JP1)
1 2.54mm jumper shunt (JP1)
2 1MΩ vertical multi-turn trimpots (VR1,VR2)
4 tapped spacers, M3 x 6.3mm
5 M3 x 5mm screws
1 M3 nut

Semiconductors

1 LMC6482AIN dual CMOS op amp (IC1)
1 LM358 dual op amp (IC2)
1 7555 CMOS timer (IC3)
1 LM2940CT-5.0 3-terminal 5V low-dropout regulator (REG1)
1 3mm red LED (LED1)
1 BC337 NPN transistor (Q1)
1 BC327 PNP transistor (Q2)
2 1N4004 1A diodes (D1,D2)
2 1N4148 diodes (D3,D4)
1 1N5822 3A Schottky diode (D5, optional - see text)

Capacitors

1 470µF 16V PC electrolytic
4 100µF 16V PC electrolytic
4 10µF 16V PC electrolytic
1 1µF 16V PC electrolytic
3 100nF MKT polyester

Resistors (0.25W, 1%)

2 1MΩ	1 4.7kΩ
1 220kΩ	1 1.8kΩ
1 100kΩ	4 1kΩ
1 47kΩ	1 150Ω
1 12kΩ	2 4.7Ω 5W
4 10kΩ	

With no signal passing through the differentiator, the voltage applied to the non-inverting input via the 10kΩ resistor to IC2b is 2.5V. Since the inverting input is at 2.27V, the output of IC2b will be high, at around +4V. This output goes low when the signal from JP1 drops below the 2.27V threshold. The associated 1MΩ feedback resistor provides a degree of hysteresis so that IC2b's output does not oscillate at the threshold voltage.

Relay timer

IC2b's output drives the pin 2 trigger input of IC3, a 7555 timer, via a 1kΩ resistor. IC3 is triggered when pin 2 drops below 1/3rd the 5V supply, at +1.67V. When triggered, IC3's output at pin 3 goes high, turning on transistor Q1 and Relay1. Diode D2 is connected across the relay coil to quench the spike voltages that are generated each time transistor Q1 turns off. Q1 also drives LED1 via a 1.8kΩ resistor to indicate whenever the relay is energised.

Before IC3 is triggered, its pin 3 output and its discharge pin (pin 7) are both low. So pin 7 causes the negative side of the 1µF capacitor to be pulled toward 0V via a 150Ω resistor.

Whenever IC2b's output goes low it also turns on transistor Q2, wired as an emitter follower. The transistor keeps the negative side of a 1µF capacitor tied at 0V. This keeps the 1µF capacitor charged while ever IC2b's output is low.

When IC2b's output goes high, Q2 is off and the 1µF capacitor discharges via trimpot VR2 and the series 1kΩ resistor, so that the negative side of the capacitor rises toward the 5V supply. When the negative side of the 1µF capacitor rises to 2/3rds of the 5V supply (about +3.3V), the threshold voltage for pin 6 is reached. At this point, pin 3 goes low and transistor Q1 and the relay are switched off. IC3's timing period can be set from around 100ms up to one second, using VR2.

Power-up delay

The components connected to pin 4 of IC3 are used to provide a power-up delay. When the vehicle ignition is switched on, the Quick Brake circuit is prevented from operating the relay for a short period. The delay components comprise a 470µF capacitor, diode D4, and 47kΩ and 220kΩ resistors. When power is first applied to the circuit, the 470µF capacitor is discharged and so pin 4 is held low. This holds IC3 in reset so its pin 3 cannot go high to drive Q2 and the relay.

IC3 becomes operational after about two seconds when the 470µF capacitor charges via the 220kΩ resistor to above +0.7V. The 47kΩ resistor is included to set the maximum charge voltage at 880mV. That's done so the 470µF capacitor will discharge quickly via diode D4 and the 47kΩ resistor when power is switched off.

Power for the circuit comes via the +12V ignition supply. Diode D1 provides reverse polarity protection and an LM2940CT-5.0 automotive regulator (REG1) provides a 5V supply for the circuitry, with the exception of the relay and LED1.

Brake light switching

As mentioned, Relay1 is used to switch on the stop lights using the normally open relay contacts which are connected in parallel with the brake switch contacts.

The normally closed contacts of the relay connect 4.7Ω 5W resistors in parallel with the brake lights, when the brakes are off (and Relay 1 is unenergised). This has been done so that the brake lights can be changed to LED equivalents without causing problems where the car's body computer monitors the brake lights for blown filaments. (If LEDs were fitted without these extra resistors, the car would display warnings on the instrument panel).

We mention these resistors at this point but the fitting of LED brake lights will be covered next month.

Fig.1 shows the brake light wiring to connector CON3 for a vehicle where the brake pedal switches are in the positive side of the lamps (ie, high side switching). In this particular case, we are showing the connection for a car which has blown filament monitoring for the main brake lights and also for the CHMSL lamp. This means that the brake pedal switch has three sets of contacts, ie, a 3-pole single-throw (3PST) switch, so that each lamp filament is isolated from the others.

So how do we fool the car's body computer into ignoring the fact that a LED equivalent may be fitted in place of an incandescent lamp in the CHMSL socket? Ideally, we would need a 3-pole double-throw relay for Relay 1 and additional 4.7Ω 5W resistors. However, since 3-pole relays are larger and much harder to obtain, we have elected to provide for this possibility by effectively connecting the CHMSL lamp in parallel with the left-hand side brake lamp via a Schottky power diode, D5.

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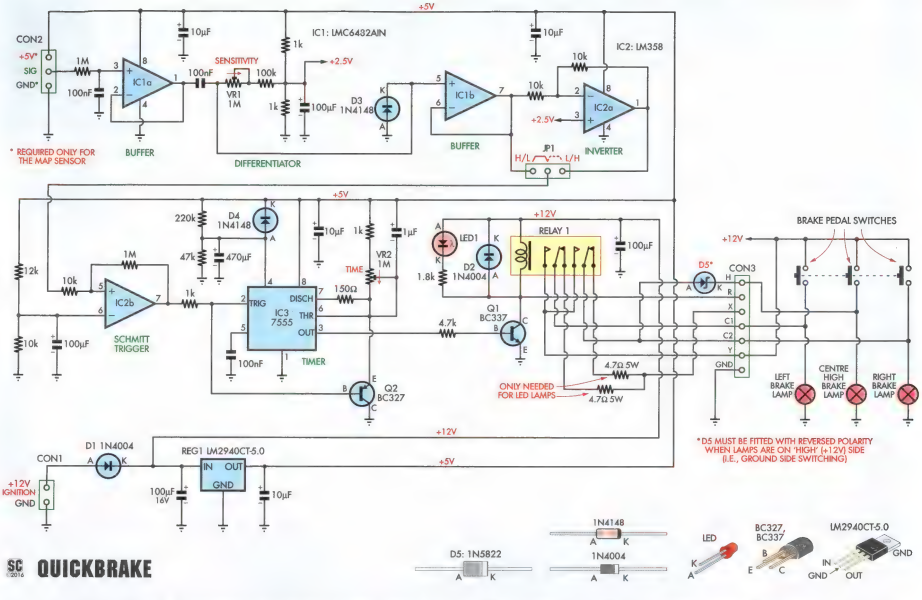


SC 2016 **QUICKBRAKE**

Fig.1: the QuickBrake circuit. IC1a monitors and buffers the signal from the throttle position sensor and feeds it to a differentiator stage which passes fast-changing signal transitions only. The differentiator's output is then buffered by IC1b and fed to Schmitt trigger IC2b via JP1 or via inverter stage IC2a and JP1. A rapid negative transition occur from the throttle position sensor (ie, during a fast throttle lift-off), causes IC2b's output to briefly go low and this triggers 7555 timer IC3 which is then enabled to briefly activate Relay1 and the car's brake lights.

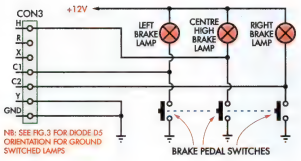


Fig.2(a): the wiring set-up when the brake lamps are low side switched and the vehicle checks for blown lamp filaments.

When the brake lights are on, the forward voltage drop across the Schottky diode will cause only a slight reduction in lamp brightness for an incandescent type and even less at the low current drain of a LED equivalent. So that takes care of isolated switching for the CHMSL lamp but does not provide a resistor to simulate a lamp filament if a LED equivalent is fitted. In that case, it will be necessary to add an additional resistor across the CON3 terminals for the CHMSL lamp (but only if a LED equivalent is fitted – more on this topic next month).

So that takes care of the high side switching of brake lamps where blown filament monitoring is a feature of the vehicle. Inevitably though, we have had to provide for other brake light switching combinations such as "low side" switching

Other switching combinations are shown in Fig.2. Let's describe these variations.

Fig.2(a) shows the set-up where the brake lights are "low side" switched, ie, in this the contacts of the brake pedal switch are in the negative side of the brake lights and again, we are catering for the situation where the vehicle has monitoring for blown lamp filaments.

Finally, Fig.2(b) & Fig.2(c) show the situations for low and high side switching where the brake pedal switch has only one contact and all the brake lamps are effectively in parallel. In this case, the vehicle cannot monitor for blown lamp filaments.

Construction

The QuickBrake is built on a PCB coded 05102161 and measuring 105.5 x 60mm. It can be fitted into a UB3 plastic utility box that measures 130 x 68 x 44mm, with the PCB supported by the integral side clips of the box. Alternatively, you can mount the PCB into a different housing on short stand-offs using the four corner mounting holes.

Fig.3 shows the component layout for the PCB. The low-wattage resistors can be installed first. Leave the 4.7Ω 5W resistors out for the moment. The respective resistor colour codes are shown in Table 1 but you should also use a digital multimeter to check each resistor before it is installed.

The diodes can go in next and these need to be inserted with the correct polarity with the striped end (cathode, K) orientated as shown. Also, be sure to install D5 with its anode orientated correctly for +12V switched or ground switched brake lamps.

Take care when installing the IC sockets (optional) and the ICs. Make sure that their orientation is correct and that the correct IC is inserted in each place.

REG1 is installed with its leads bent over at 90° so as to fit into the allocated holes in the PCB. The regulator is then secured to the PCB using an M3 x 5mm screw and M3 nut before its leads are soldered.

The 3-way pin header for JP1 is installed now with the shorter pin length side inserted into the PCB, leaving the longer pin length for the jumper link.

The two 5W resistors can be installed now but these are only required if you intend replacing the brake lamps with LED equivalents.

The capacitors can now go in. The electrolytic types must be installed with the polarity shown, with the plus side oriented toward the sign as marked on the PCB. The ceramic and polyester capacitors (MKT) can be installed with either orientation on the PCB.

Install transistors Q1 and Q2 next. Make sure that Q1 is a BC337 and Q2, BC327. LED1 must be installed with its anode side (longer lead length) orientated as shown. The LED is normally just used to provide a relay-on indication that is useful when testing, so the LED can be mounted close to the PCB.

VR1 and VR2 can go in next. Both are 1MΩ multi-turn top-adjust types and the screw adjustment needs to be orientated as shown. This is so that the slow rate adjustments set by VR1 and longer time periods set by VR2 are achieved with clockwise rotation.

The screw terminal blocks are installed with the open wire entry sides facing outwards. The 7-way screw terminal block (CON3) consists of two 2-way and one 3-way blocks which are simply dovetailed together before installing them on the PCB.

Finally, complete the PCB assembly by fitting the relay.

Initial testing

Apply power to the +12V and GND terminals of CON1 and check for 5V at CON1 between the +5V & GND terminals. If the voltage is within the range

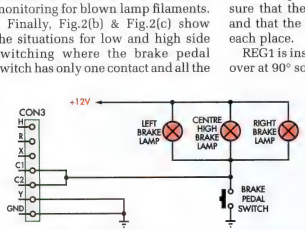


Fig.2(b): the configuration for low side switching where the lamps are wired in parallel & the brake switch has only one contact.

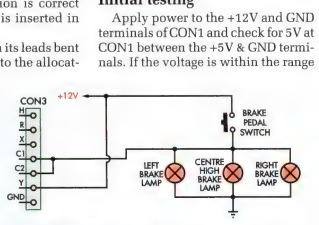


Fig.2(c): high side switching with the lamps wired in parallel. The vehicle cannot detect individual blown lamp filaments in Figs.2(b) & 2(c).

of 4.85-5.15V, then this is OK. If the voltage reads 0V, the 12V supply may have been connected with reversed polarity or D1 may have been orientated the wrong way.

Before doing any adjustments, trimpots VR1 and VR2 should be wound anticlockwise until a faint click is heard, indicating that the adjustment is set fully anticlockwise. This sets VR1 for maximum sensitivity to sensor voltage change and VR2 for minimum relay on-time. Then place a jumper link in the H/L position.

To simulate a throttle position sensor, connect a linear 10kΩ potentiometer to CON2, with the outside terminals connected to GND and +5V and the wiper to the SIG (signal) input.

Adjust the 10kΩ potentiometer clockwise and then wind it quickly anticlockwise. The relay should switch on and LED1 should light. You can now check the effect of adjusting VR1 clockwise; this will mean that the 10kΩ potentiometer will need to be rotated more quickly anticlockwise before the relay switches on.

VR2 can then be rotated clockwise to set more on-time for the relay. We suggest one second.

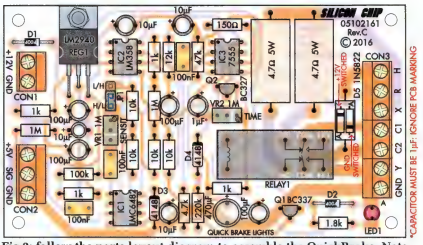
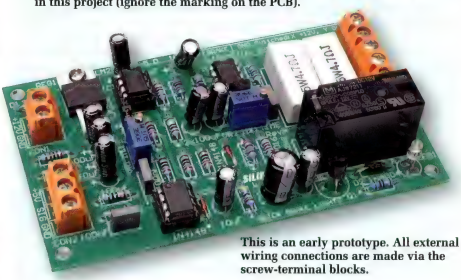


Fig.3: follow the parts layout diagram to assemble the QuickBrake. Note that the electrolytic capacitor immediately to the left of VR2 must be 1µF in this project (ignore the marking on the PCB).



This is an early prototype. All external wiring connections are made via the screw-terminal blocks.

Installation

Most modern vehicles will have a TPS and so this sensor can be used as the signal source for the QuickBrake. In this case, only the signal input terminal is used and connected to the signal wire from the TPS which will normally be connected to the accelerator pedal. In some cases though, it may be located on the inlet manifold butterfly valve.

The connections can be found by checking the wiring against a schematic diagram and connecting to the wiper of the TPS potentiometer. Alternatively, you could probe the TPS wires to find the one that varies with throttle position. Note that some TPS units will have two potentiometers plus a motor. Use the potentiometer wiper output that varies with throttle pedal position.

Once you have identified the correct wire from the TPS, you can connect a wire from it to the QuickBrake PCB using a Quick Splice connector (Jaycar Cat HP-1206; packet of four). Just wrap it around the existing TPS wire and the new wire and simply squeeze it to make a safe connection.

If you have an older vehicle, then it will not have a TPS or engine manage-

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	1	220kΩ	red red yellow brown	red red black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	12kΩ	brown red orange brown	brown red black red brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❑	4	1kΩ	brown black red brown	brown black black brown brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	2	4.7Ω	not applicable	not applicable

QuickBrake Lamp Response Measurements

As part of the design work on the QuickBrake circuit, we needed to take a series of measurements to show the times for brake lamps to light in a somewhat non-typical situation. In this case, the vehicle used had an almost ideal throttle and brake pedal set-up, with both pedals being quite close together, no offset to the right and with similar height above the floor (ie, almost co-planar).

We then did a lot of practice brake applications and we determined that the quickest anyone could move his or her foot from the throttle to the brake in a simulated emergency was close to 110ms, ie, much faster than the typical times for most drivers, as quoted at the start of this article.

A phototransistor was used to monitor the brake lamp brightness. We arranged the phototransistor as an emitter follower so that its voltage rises with increasing light level. The phototransistor was placed away from the brake light at a distance where full brightness of the lights gave maximum positive voltage output and zero for lights off.

We found this positioning to be quite critical. If the phototransistor is too close to the brake lamp, the phototransistor output will be at maximum when the lamp is barely glowing. This would give a false indication. By contrast, the phototransistor positioning for LED lamps is not at all critical since their response is extremely fast.

Scope shots

All of the accompanying oscilloscope shots show the TPS voltage as the top yellow trace (channel 1). In each case, the voltage falls from about +4V down to about 0.8V when the foot is lifted rapidly from the accelerator pedal. We set the trigger point sensitivity (VR1) for the QuickBrake at mid position, to give a reasonable reference point. The lower blue trace on each shot is the phototransistor output monitoring the brake lamp.

There are also small differences for the same lamps when comparing their QuickBrake response to that when just using the brake switch. These differences are due to variations in the time taken to press the brake pedal and also depend on whether the lamp filaments have fully cooled between each test.

Scope1 shows the response of the QuickBrake. You can see that the LED (blue trace) comes on as the TPS voltage (yellow trace) drops just below 2V. The response time is about 10ms; the time for the relay to close.

Scope 2 shows what happens without QuickBrake and shows a time delay of about 120ms between the same 2V threshold for the TPS voltage and the LED actually lighting up.

Scope3 shows the QuickBrake response time when switching a 5W filament lamp (although typical CHMSL lamps have a higher rating and hence a longer response time). Here the response time is about 80ms or thereabouts for reasonable but not full brightness. Full brightness is achieved at about 150ms.

Scope4 shows the same 5W lamp response when being switched by the brake pedal alone (ie, QuickBrake out of circuit). Note that the timebase is now 50s/div, so the time from TPS threshold to full brilliance is more than 200ms.

Scope5 shows the QuickBrake response with a 21W lamp and is typical for most cars. The timebase is 100ms/div and the time taken to fully light approaches 350ms.

Scope6 shows the 21W lamp response when switched by the brake pedal (ie, QuickBrake out of circuit). Compare this with Scope5.

These scope shots certainly demonstrate the effectiveness of the QuickBrake circuit but they also show an even bigger improvement when LED lamp equivalents are fitted. That will be our story for next month.

ment. In this case, a MAP sensor can be used to connect to the inlet manifold so as to monitor the inlet pressure.

Using a MAP sensor for manifold pressure readings is suitable only for petrol engines though, not diesels. The 5V supply provided on the QuickBrake PCB at CON2 can be used to supply the MAP sensor. It is not critical which MAP sensor is used. A secondhand MAP sensor can be obtained from a wreckers' yard. Holden Commodore MAP sensors are common. Alternatively, you can obtain a new one from suppliers such as: **www.cyberspaceautoparts.com.au/contents/en-uk/d3721_Holden_Map_Sensors.html**

TPS & MAP sensors

The voltage output from electronic pressure sensors such as a MAP sensor usually decreases with increasing vacuum; typically 0.5V with a complete vacuum and up to about 4.5V at atmospheric pressure. This is similar to a TPS sensor which has an output of about 0V at no throttle and 5V at maximum throttle.

For QuickBrake to work, the JP1 position should normally be H/L but L/H should be used if the voltage varies in the opposite direction when the throttle is released. Note that the TPS output will only vary with throttle position when the ignition is on. A MAP sensor will only vary its output with changes in manifold pressure, ie, when the engine is running.

Wiring the brake lights

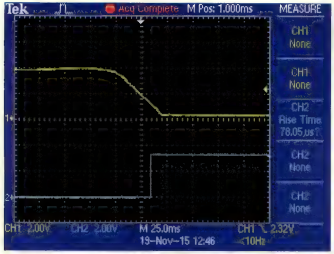
The brake light wiring is relatively straightforward. You require a connection across the brake switch contacts, using the C1, C2 and Y terminals on CON3 on the QuickBrake PCB. As noted above, the circuit of Fig.1 shows the wiring where the brake lights are "high side" switched and with blown filament monitoring. Fig.2 shows the other possible set-ups.

Most constructors will probably elect to install the QuickBrake PCB (in a plastic case) somewhere under the dashboard, giving easy access to the TPS wire and the 12V feed from the ignition switch. Others may find it more convenient to install it in the boot but this will mean running longer wires from the TPS and the +12V feed from the ignition switch.

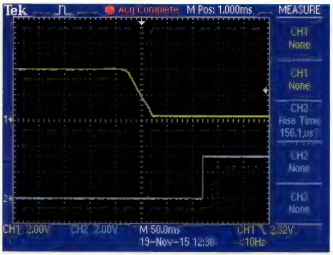
Final set-up

VR1 should adjusted so that the relay switches on when the accelerator pedal is released suddenly. At the same time, it should be set so that normal accelerator movements to do not trigger the relay. That means adjusting VR1 clockwise until normal throttle movements are not detected.

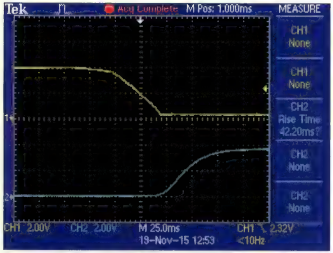
Trimpot VR2 is set so that the relay stays on long enough for the brake pedal to be pressed before it goes off. This prevents blinking of the stop lamps when the brakes are applied.



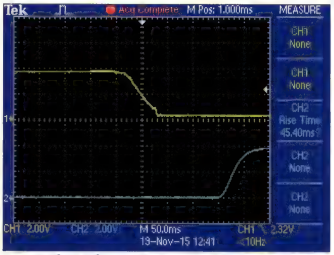
Scope 1: this scope grab shows the response of the QuickBrake. The LED (blue trace) comes on as the TPS voltage (yellow trace) drops just below 2V. The response time is about 10ms; ie, the time for the relay to close.



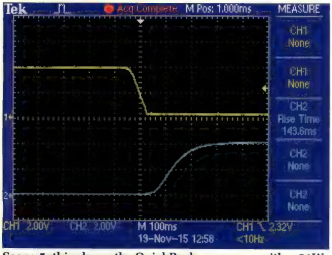
Scope 2: this shows what happens without the QuickBrake. There is a time delay of about 120ms between the same 2V threshold for the TPS voltage and the LED actually lighting up.



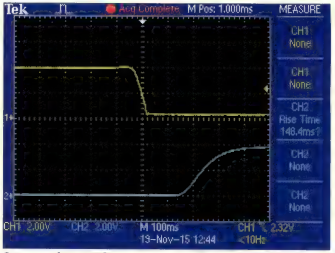
Scope 3: the QuickBrake response time when switching a 5W filament lamp. Here the response time is about 80ms for reasonable but not full brightness.



Scope 4: the 5W lamp response when being switched by the brake pedal alone. The timebase is 50s/div, so the time from TPS threshold to full brilliance is more than 200ms.



Scope 5: this shows the QuickBrake response with a 21W lamp and is typical for most cars. The timebase is 100ms/div and the time taken to reach full brightness is 350ms.



Scope 6: the 21W lamp response when switched by the brake pedal (ie, QuickBrake out of circuit). Compare this with Scope5; the QuickBrake makes a big difference. SC

CIRCUIT NOTEBOOK

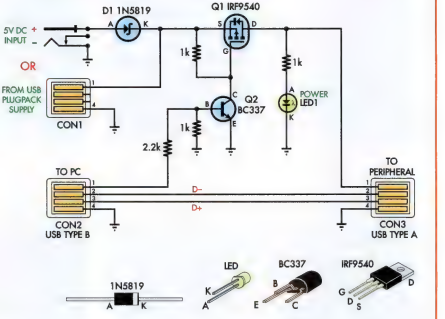
Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

USB power injector

Many computers and most laptops do not have sufficient USB ports. You can partially solve this problem by using a USB hub but if you have one or several USB peripherals which call for more than the usual amount of current, an unpowered hub may not solve the problem because the available power from your computer is simply inadequate.

If you don't have a powered hub, you can use a USB power booster which runs from an external 5V supply. This booster circuit uses a standard 5V plugpack supply with USB or DC socket connectors to supply the required power to your USB peripheral devices. This 5V supply is fed either via Schottky diode D1 from the DC socket or directly via a USB socket from the plugpack. Only one of these sockets should be used.

When the computer's USB outlet is connected, its 5V rail drives the base of NPN transistor Q2. This in turn switches on Q1, a P-channel Mosfet, by pulling its gate negative with respect to its source and this allows the 5V external supply to be fed through to USB outlet port CON3 and to LED1 via a 1kΩ current-limiting resistor. Then you can connect the booster to feed the hub.



In fact, it may be possible to build this USB power booster circuit inside the case of a typical USB hub. No heatsink should be required for Mosfet Q1.

John Clarke,
SILICON CHIP.

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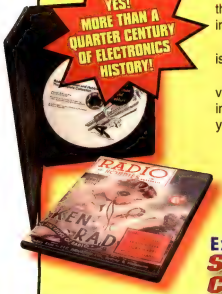

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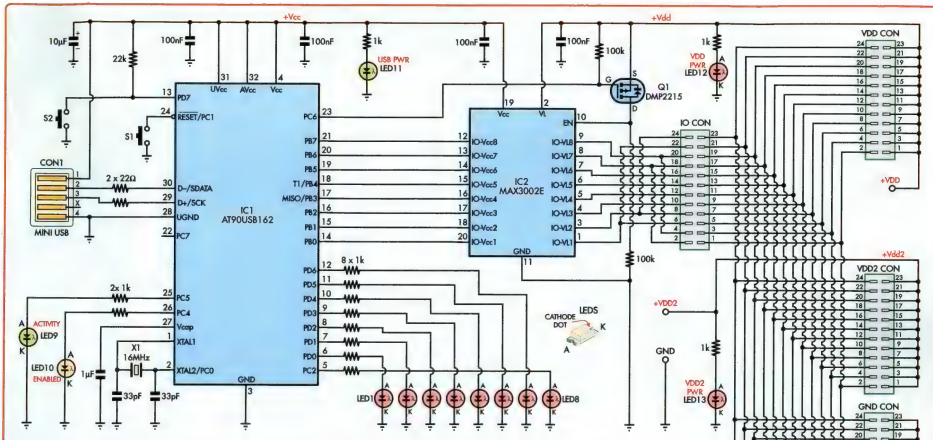


Bidirectional interface

This is a high-speed, bidirectional 8-bit digital interface for a PC which can interface with circuits operating at 1.2-5V. This allows it to communicate with virtually any digital circuit which uses standard I/Os.

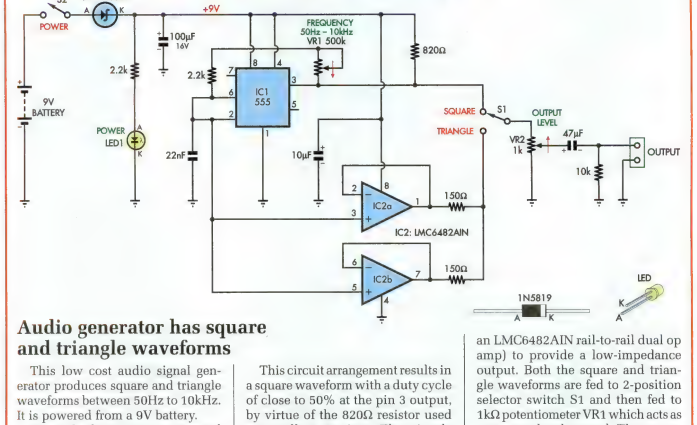
It's based on a bidirectional level shifter (MAX3002E) and a USB microcontroller. The level shifter can handle 20Mbps signalling however the micro runs at 16MHz and can't pump out data that fast. Typically, it can send and receive at over 1MB/s peak.

It uses "libusb" and interfaces with custom software on the PC to do whatever task is required. It was designed to test custom-made high-speed logic ICs. Modern high-speed ICs typically use low-voltage I/Os, often 1.2V or 1.5V. The software is modified to perform whatever tests are required on the IC and report the results to the user.

The I/Os are connected to a dual row pin header on which shorting blocks are placed to connect the signals to various pins on the multiple IDC sockets which connect to the device(s) under test. These headers can also be used to feed V_{DD}, V_{DD2} or GND to any of those test pins. V_{DD} and V_{DD2} are independent external supplies with V_{DD} used as the I/O signalling level.

The software and EAGLE PCB file are available at www.siliconchip.com.au

Nicholas Vinen,
SILICON CHIP.



Audio generator has square and triangle waveforms

This low cost audio signal generator produces square and triangle waveforms between 50Hz to 10kHz. It is powered from a 9V battery.

A standard 555 timer connected as an astable oscillator produces the waveforms but instead of the conventional connection for pins 2, 6 & 7, with the timing capacitor being periodically discharged via pin 7, the 22nF timing capacitor is connected to pins 2 & 6 and is charged and discharged via a series connected 2.2kΩ resistor and 500kΩ potentiometer VR1, wired as a variable resistor (rheostat).

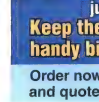
This circuit arrangement results in a square waveform with a duty cycle of close to 50% at the pin 3 output, by virtue of the 820Ω resistor used as a pull-up at pin 3. The triangle waveform (the charge and discharge waveform on the capacitor) is taken from commoned pins 2 & 6. This output has quite a high impedance (depending on the setting of VR1) and any loading from a following circuit will prejudice its operation in terms of operating frequency and duty cycle.

Therefore the triangle signal is fed to two paralleled op amps (in IC2, an LMC6482AIN rail-to-rail dual op amp) to provide a low-impedance output. Both the square and triangle waveforms are fed to 2-position selector switch S1 and then fed to 1kΩ potentiometer VR1 which acts as an output level control. The output signal from VR1 is AC-coupled to the output.

Note that the triangle waveform output is not perfect as it is formed using a portion of the exponential curves produced when charging and discharging a capacitor through a resistor. The output frequency range is typically 50Hz to 10kHz.

John Clarke,
Silicon Chip.

Got an interesting circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the Silicon Chip on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au or post it to Silicon Chip, PO Box 139, Collaroy Beach, NSW 2097.



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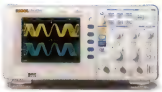

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SERVICEMAN'S LOG

Tools, old scopes & my hoarding habits

Dave Thompson*

I might as well confess up-front; I have a weakness for good tools and a penchant for keeping stuff that might come in handy one day. Unfortunately, all those spare parts I keep did me no good when I recently tried to repair an old oscilloscope but they did come to the rescue with an electric screwdriver.

There is an old saying bandied about factories and workshops, typically by older and wiser guys, that "a good engineer never blames his tools". I first heard this many years ago as a wet-behind-the-ears apprentice engineer and given what I do now, one can substitute the word "serviceman" for "engineer" in that saying.

Basically, the premise remains the same; if I make a mistake, blaming my tools is a cheap cop-out because the buck ultimately stops with the one holding the hammer.

I was very fortunate to begin my engineering training in workshops rated as the best in the world in their respective fields. It was all very new to me at the time but I can still clearly recall the day we were issued our first toolkit.

This initial basic tool issue differed between apprentices, depending on what one was eventually going to be doing. After that, over the following five years, more tools were added to our kits as we were seconded to the many specialised workshops. As a result, by the ripe old age of 20, I had a set of the best tools money could then buy.

I also always remember that first day riding home on my motorbike with my shiny new, bright-orange, folding, metal toolbox balanced precariously on the bike's curved duck-tail fairing. It was restrained with nothing more than a bungee cord, with my (also freshly-issued) folded-up overalls protecting the bike's paintwork and my left hand (when it was free) steadying things as I headed home. I was taking it as easy as I could and was doing swimmingly until I drove past a bus-stop brimming with workers who were also heading home.

As Murphy's Law dictates, that was the exact spot for something to go wrong and so it did. With an unstoppable slide, the toolbox slipped out from under the bungee and away from my restraining hand and the next memory I have is the horrifying view in my mirrors as it tumbled down the road, bursting open and shedding my beautiful new tools all over the road.

I sheepishly circled back to the sound of applause and whistles as the waiting minions scored my performance. Several braved what traffic there was in those days to help pick up the tools and fortunately those that hit the road were none the worse for their adventure.

I resolved at that point to never again carry anything on a bike (or any other vehicle) without the proper restraints and I never have.

But I digress; by the time I took those first steps toward becoming an aircraft engineer, I'd already learnt the value of good tools. I'd also learnt the value of doing a job properly and that no matter how good I thought I was, humility and an open mind were essential if I was to become better at my work.

My father imparted this knowledge to me over the years I worked with him in his well-equipped home workshop. During that time, we made various electronic gadgets, built many radio-controlled model aeroplanes, crafted custom-made replacement parts and components for all types of model hobbyists and tinkered with projects of both Dad's and my own conception. He even helped me by milling custom bridges and other parts for my early attempts at luthiery, ie, building guitars and other stringed instruments.

This is also where I developed my life-long interest in electronics and in that respect I was also greatly influenced by Dad's younger brother, Roger, who lives in Melbourne and has represented the Aussie branch of the Thompson family for the last 50 years. My uncle's electronics workshop was also a place of pilgrimage for me during my formative years and it's also where I likely picked up my habit of saving everything just in case I might need it one day.

Now I'm not one of those hoarders who can no longer get in the front door of his house and has to sleep standing up and neither is Roger. However, like him, I dislike throwing out something that still has usable components. From past experience, I can almost guarantee that the moment I throw something away, a use for it will arise the very next day and this is, of course, another variation of Murphy's Law.

Admittedly, my penchant for keeping stuff sometimes causes a little domestic disharmony, especially if said stuff is overflowing into visible space. However, as long as it is out of sight, I can usually get away with it.

My semi-frequent trips across the pond as an apprentice engineer always seemed quite exciting, due to the pros-

Items Covered This Month

- Dave's penchant for keeping stuff
- Panasonic DMR-EX77 DVD recorder
- The humming spring reverb
- Aaron BS-612 oscilloscope repair

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pect of poking around Roger's workshop to see what goodies he'd acquired since my last visit. I also spent some long, hot Melbourne summer evenings poring over his vast collection of electronics magazines and videos or simply sitting and listening to his servicing stories.

At the time, he had a TV hire and service company, as well as a business installing large-scale PA systems, and since I was very much into audio electronics, there was always something interesting he could show me. I never came home empty-handed and still have many of the gadgets Roger gave me sitting in my workshop today.

Sadly, I haven't been back to Melbourne since I left the airline and discovered that air-travel is expensive; or at least it is compared to what I had been paying. However, Roger and I still talk from time to time via the Internet and it was during one of these chats some time ago that he offered me an older-style (CRT) oscilloscope that he'd come across in his travels. He said it worked fine except for a dim trace and I could have it for the cost of shipping it over to Christchurch.

At the time, I didn't own a scope and so I readily agreed to the deal. I was quite excited; there is nothing quite like getting almost-free electronic goodies, especially useful test gear like an oscilloscope. I must admit that I was a bit worried about shipping it over, given some of the horror stories one hears about cargo workers and courier drivers, but I really had nothing to worry about. The "fragile" stickers plastered all over the package must have worked because the scope arrived none the worse for wear, ready for me to troubleshoot the faded trace.

Now, people may think me cheap given that digital scopes are a dime a dozen these days from the likes of Ali-Express but all this transpired quite a few years ago now. At the time, even a half-decent analog scope still cost more than triple what it cost me to ship this one over, so I was prepared to take the risk.

The unit turned out to be a Goodwill GOS-522 dual-trace, 20MHz oscilloscope and for the type of work I do, it would be an ideal piece of teat gear – provided, of course, that I could get it to work properly! I'd actually been contemplating buying a scope for a while and at one stage, even considering building one of the excellently-

~NOW I'M NOT ONE OF THOSE HOARDERS WHO CAN NO LONGER GET IN THE FRONT DOOR OF HIS HOUSE

presented DIY models available on the web. The problem was that I didn't want a PC-based scope and the few CRT-based models that were out there utilised expensive and/or hard to obtain valves, switches and transformers. So the idea was a non-starter and while I drooled over those for sale in online auctions and the digital models in the magazine ads, I couldn't rationalise spending many hundreds of dollars on something I would only use every now and then. After all, there isn't a lot of call for a scope in the PC-repair business.

In the end, getting a free "fixer-upper" was an opportunity I wasn't going to turn down.

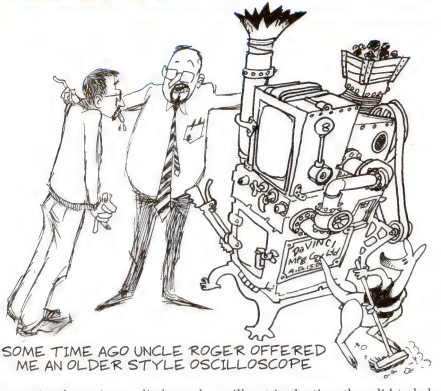
From the outset, I knew that I needed a circuit diagram if I was going to have any chance of fixing it but a web search threw up three-fifths of sweet nothing. There were plenty of oscilloscope schematics and circuit diagrams floating about but nothing resembling the GOS-522, so I did what any enterprising serviceman would do and emailed the manufacturer (who still has a web presence), outlining my problem and asking politely if they possibly had a circuit diagram for this particular model.

Lo and behold, a reply quickly came back saying that they could provide a circuit diagram as long as I promised not to sell it or make money from it. I replied assuring them that this was for my own personal use and not long after that I received high-quality scans of five pages from the workshop service manual. These scans contained the complete circuit diagram, the bill of materials (BoM) and test-point voltage charts that I could use to help track down the problem.

This scope is quite an old-school design and used single-sided phenolic PCBs stuffed with full-sized discrete components. Fortunately, the ICs used were all common types and still readily available (if I didn't already have them in my parts boxes), the only really specialised parts being the power transformers, some of the switches and, of course, the tube itself.

These older scopes can sometimes run quite hot and given there is HT involved, it doesn't pay to skimp on component quality. Anyway, after giving everything the once-over with a magnifying glass under a decent light, I found several electrolytic capacitors that looked a bit dodgy. In the end, I replaced all the electros that I could find, swapping them out for "high-spec" modern equivalents.

Those "iffy" electros didn't explain the dim trace but after replacing them, I did discover several test-point voltages in the focus and dimming circuits that were outside their specified limits. As a result, I removed all



SOME TIME AGO UNCLE ROGER OFFERED ME AN OLDER STYLE OSCILLOSCOPE

the associated transistors, diodes and zener diodes and replaced them with new components. Most of the transistors were older-style 2SA-series parts, so I researched their properties using datasheets downloaded from the web so I could select suitable modern-day substitutes. Fortunately, I had all these in my transistors parts box and I tested each one before fitting it, to ensure I wasn't introducing any new problems.

Despite my efforts, the trace remained stubbornly dim and so, as a last resort, I emailed the Goodwill people and asked for help. Living up to their name, they subsequently spent a lot of their time emailing suggestions (most of which I'd already done) and detailing various things I could try but in the end, they came to the inevitable conclusion that it was the tube itself. By this time, I'd already come to the same conclusion but had been hoping that I was wrong.

Of course, I was grateful that Goodwill put in the time they did to help me and I felt like buying one of their modern scopes by way of thanks. However, I really couldn't justify the money, considering how infrequently it would be used.

Unfortunately, they no longer held stock of the tube and couldn't provide any suggestions on where I could buy one either. I ended up putting the scope under the bench and there it sits in the hope that, one day, the searches I've set up on online auction sites might generate a lead to one. I posted on a couple of forums as well and ironically have helped out half a dozen blokes with the circuit diagrams (with Goodwill's blessing), so some good did come from the experience.

Battery-powered screwdriver

Some time ago, I urgently needed a battery-powered screwdriver and in my haste, I broke one of my own cardinal rules; I bought a cheap model from one of the big shed-type retail outlets. Now I'm not against people buying cheap tools but personally I usually try to buy the best I can afford. At the time though, we didn't have a lot of cash-flow and so I ended up with a cheap device

The unit came with two LiPo batteries and had a semi-decent clutch and DC braking. However, it still felt and sounded "cheap", as all such tools do. Long story short, it did the job I needed it for and since then has done a little work here and there when ever I've needed a portable driver.

Just recently, I fished it out for a job and, as I usually do, held the chuck ring in my left hand and squeezed the trigger with my right to run the unit backwards to open out the chuck to take the drill bit. The drill I wanted to use was half-inch type, the maximum this particular chuck could take, and from experience I knew I'd need to open the chuck all the way. As a result, I ran it to the end, until the chuck ring wouldn't turn any further.

I then put the drill in and, after switching drive direction, again held the chuck's ring while pressing the trigger to do the chuck up. It's a technique I learnt from Dad years ago before keyless chucks became the norm and I always use it, regardless of the type of chuck.

Anyway, the chuck closed onto the large bit's shank as expected and I set about drilling the hole. However, the bit was all over the place and I soon discovered that one of the chuck's three jaws hadn't closed with the others, making the grip somewhat lopsided. It turned out that it had somehow slipped off the inside mechanism and nothing I could do would move it back so that it engaged with the rest of the chuck.

I did a few searches regarding the problem on Google but, in the end, the only thing I could do was replace it. This is quite straightforward; inside the chuck is a pan-head bolt that screws with a lefthand thread into the screwdriver's main shaft. This is usually a pozi-drive/Phillips type bolt but sometimes an Allen-headed bolt is used.

Once that's out, a large Allen key is clamped in the chuck and, with the unit in the lowest gear possible, smacked with a hammer in an anti-clockwise direction until the chuck loosens and unscrews from the main shaft. This was a bit difficult since I had only two jaws to hold the Allen

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key but I eventually got it off.

This where my penchant for keeping stuff (aka my hoarding tendencies) came in handy; I replaced the chuck with one I'd reclaimed from a discarded electric screwdriver a friend was throwing away. Which brings me to the moral of this somewhat "electronics-less" repair tale; I don't throw anything out that I might be able to use tomorrow! Well, it works for me.

Panasonic DVD recorder

Sometimes when a piece of electronic equipment fails, it pays to put it to one side until similar faulty units can be picked up for just a few dollars (or better still, for free). Depending on the fault, it's often then possible to use the salvaged gear to repair the original unit, as B. C. of Dungog, NSW relates . . .

Over a period of years, I have repaired many DVD recorders of various brands, with the failure of the laser pick-up assembly usually being the end-point of their lives. In fact, I recall a popular Asian model that invariably required the DVD drive unit to be replaced within the warranty period.

That wasn't the case with Panasonic DVD recorders, though. Their laser pick-ups had a good lifetime although there was an occasional DVD drive failure in some of the newer models.

These latter models were in an enclosed sheet metal box with four flying membrane type leads that plugged into sockets along one edge of an interface PCB. In fact, when a faulty Panasonic DVD drive unit was replaced under warranty, it came with the interface PCB. The bare laser pick-up assembly, on its own, wasn't available as a spare part in Australia.

Recently, I was asked by a friend to test his Panasonic DMR-EX77 HDD/DVD recorder which was having problems with DVD discs. On the workbench, I tested the DVD drive unit by first loading some commercial pre-recorded CD and DVD discs, then some recordable DVD-RAM, DVD-RW and DVD-R discs. The drive unit wouldn't recognise any of these disc formats, so it was clearly faulty.

Considering this was a standard definition (SD) HDD/DVD recorder, it wasn't economical to purchase and fit a new DVD drive unit and interface PCB. As a result, we decided to put his machine on the back burner, with the slim hope that, one day, a similar machine might turn up with a faulty motherboard or power supply board.

Eventually, a Panasonic DMR-ES15 DVD recorder turned up. Although a different model to my friend's recorder, it uses a compatible DVD drive unit but this too was found to be faulty. More time went by and then a second DMR-ES15 turned up at a recycle shop. This one had a storm-damaged power supply and so the power supply board from the first DMR-ES15 was swapped over. Unfortunately, this second unit also had a faulty DVD drive!

A few more months went by and then yet another DMR-ES15 turned up at the recyclers. This one also had a storm-damaged power supply and so the good power supply board was transferred into this machine. The test discs were then all loaded one by one and all were recognised. I then found that I was able to record to a DVD-R disc and play it back, so this DVD drive worked perfectly.

My friend's DMR-EX77 recorder was then dusted off and the good DVD drive unit transplanted into this machine. The machine then proved to be functional and is now back in service.

So persistence can pay off in cases like this. It's just a matter of waiting until similar faulty machines come along that can be picked up for next to nothing and salvaging the required part.

The humming spring reverb unit

What are friends for if you can't fix an old valve reverb unit for them? A. L. S. of Turramurra, NSW substantially rebuilt one such unit and modified it to get rid of a serious hum problem. Here's his story . . .

One of my friends, an old rock-star guitarist from the 1960s, has two sons who inherited his talents and have themselves become terrific guitarists. Now Dad has become their "roadie" and buys and maintains all their electronic equipment.

What most people don't understand about rock-star "roadies" is that their electronic abilities are often more along the lines of "a little knowledge is a dangerous thing". I've often found weird set-ups where circuitry has been rearranged, valves changed and earths disconnected etc in an attempt to "improve" the tonal quality of an amplifier or to solve hum problems due to earth loops (it's never a good idea to disconnect a mains earth though, as this can compromise safety).

The following account is a typical

This underside view of the valve reverb unit shows the spring assembly.

example of how things can go wrong in the rock world. One afternoon, the doorbell rang and there was my friend with an ancient valve reverb unit under his arm. "I want the boys to hear a real reverb unit", he told me. "The new electronic units don't even come close to the ones we used to use. This unit has a fantastic sound but it has too much hum. Can you fix it?"

I had no choice; he's been a good friend for 20 years so I said that I would see what I could do. As soon as he'd left, I suddenly recalled the words of my old boss after I did a similar repair job in 1972. "Why did you fix that old stuff? You will only have it returned for some other fault . . . forever!"

It was good advice but those words soon faded and I opened the unit up. I couldn't read the brand as it had long been obliterated by beer and Saturday night gigs which had obviously got completely out of hand. I later found out that my friend was in the habit of kicking the unit for a special effect – a sort of crashing, booming sound. Of course, that can't happen with solid state delays!

A good brand would have been "Pandora" because inside the box was a bit of a disaster . . . and I had opened it. I immediately saw that the 6V4 rectifier valve had cracked and had lost its vacuum, while the 12AX7 (ECC83) preamp valve didn't look too healthy either. And the 6BQ5 (EL84) driver had fallen out of a very loose socket, possibly due to too much kicking?

But that's wasn't all – the whole chassis inside the box was wrapped in metal mosquito netting and wired to ground! Apparently someone had heard about Faraday cages which, as you probably know, are designed to prevent electromagnetic radiation from penetrating. However, a Faraday cage won't stop any hum which originates from mains-powered circuitry!

The earth connection to mains had

Aaron BS-612 Oscilloscope Repair

B. P. of Dundathu, Qld likes picking up stuff at bargain prices on eBay. The problem is, not all bargains are in working order, despite what the seller claims. He's how he recently resurrected one such faulty bargain . . .

I recently picked up an Aaron BS-612 20MHz oscilloscope on eBay. It was listed as being in good working order and even came with an instruction manual, so it seemed like a good deal.

After unpacking the unit, I turned it on but there was no display. The power LED was on and the Trigger LED would flash when the trigger knob was turned but there was nothing on the screen.

Initially, I thought that something might have come loose during transport, so I unplugged the power cable and removed the top cover. Nothing seemed amiss, so I removed and tested the three fuses, one at a time. All were good and were refitted in turn. After re-fitting the top cover, I turned the unit on again and this time I had something on the screen. I then proceeded to fit a probe to Channel A and calibrate it, using the inbuilt square-wave generator.

Well, this didn't go according to plan, because I got all sorts of variations on the screen. Sometimes it produced the correct square wave but at other times an "L" plus an inverted "L" or just a series of lines. The focus was also giving problems, with channel B being incorrectly focused when channel A was correct. In addition, both the AC-GND-DC switches were intermittent.

After further testing by measuring a 12V battery, I found that Channel B was not showing the correct voltage. In fact, it was around half what Channel A showed on the same setting. So much for the idea that the oscilloscope was in good working order. I was so disgusted that I just turned it off and put it away for the time being.

A few days later, I turned it on again and once more, nothing came up on the screen. It was time to check it out further, so after disconnecting it from the power, I removed the top cover and located the power supply unit. I decided that this would be a good place to start but removing the supply also requires the removal of the bottom cover, which is held on with just two screws.

I had noticed that there were many similar plugs attached to the power supply board, so I decided to mark them to ensure that I didn't put anything back in the wrong place when it came time to reassemble it. Having done that, I removed all the plugs, then turned the oscilloscope upside down and removed the four screws that held the power supply board in place. I found it rather strange that the two front brackets had a nut under them as a spacer and that the associated screws were a little longer than the two screws at the back of the board.

With the power supply board in my hand, the first thing I did was to test all the electrolytic capacitors with my ESR meter. Surprisingly, for such an old piece of equipment, all the capacitors tested good, which is more than I can say for a lot of far more modern electronic equipment I have worked on in recent times. They certainly knew how to make reliable capacitors back then. What's more, this oscilloscope uses a conventional power transformer rather than a switchmode power supply and that would also have a lot to do with the longevity of the electrolytic capacitors.

The next thing I did was to use a magnifying glass to help look for suspect solder joints. The soldering turned out to be in quite good condition, although I did touch up a few joints that looked slightly suspicious. Nothing else seemed amiss on the power supply board, so I refitted it, then turned the oscilloscope up the right way again and refitted all the plugs.

That done, I sprayed the two faulty AC-GND-DC switches with some switch cleaner/lubricant and gave the switches a good workout. Both switches are slide types and are accessible on the back of the front panel from inside the case.

Next, I powered the oscilloscope up and proceeded to set the voltage on the two main rails. I first connected my multimeter between the second pin on Connector P3 and Ground and set VR9 to give the correct reading of +120VDC. This rail was quite close and didn't need much adjusting. I then decided to set the -1.9kV rail by adjusting VR7. It was very fortunate and timely that I had recently purchased a Vici VC99 multimeter on eBay, because none of my other multimeters would read over 1000V DC.

I checked the voltage between the second pin on Connector P2 and Ground and found that it was -2002V DC, which was way over the required -1.9kV DC. However, by carefully

also been disconnected, apparently by someone who had heard that earth loops can cause hum. Unfortunately, it wasn't possible to obtain a circuit diagram but it was fairly straightforward despite the fact that it had been somewhat "modified" over the years.

Basically it consisted of a 12AX7 twin-triode, one half of which acted as a preamp feeding an EL84 pentode. This in turn fed a spring reverb unit via a small-single-ended output transformer. The spring reverb unit, which was bolted directly to the box, consisted of a driver solenoid which activated three springs.

A detector coil, similar to the workings of a dynamic microphone, was placed at the other end of the springs and this went to the grid of the second half of the 12AX7 triode. This then provided a "line out" signal which could be fed to an amplifier or mixer.

The input coil was low impedance and measured 15Ω at 1kHz. The output coil was around 600Ω and this allowed me to determine which really was the input because the leads had been reversed at some point in the unit's life.

By now, I feared that the whole thing would be a waste of time, especially if the spring unit was faulty. So rather than wasting my last remaining 6V4 rectifier valve, I fitted four 1N4007 diodes (two in parallel across the rectifier valve socket pins) so that I could

adjusting VR7, I was able to set the voltage to the correct value. I then adjusted VR11 to set the intensity to just dim when the intensity knob was at the 9 o'clock position.

There were a few other adjustments on the power board but I didn't understand the meaning of the instructions, so I just skipped over them.

Next, I turned my attention to the Vertical Amplifier Board. I first adjusted VR5 to correct the voltage reading on Channel A (which had been very close to correct anyway) but then found that VR11 did not have sufficient adjustment to correct the voltage on Channel B, which was still showing half the actual voltage. I haven't pursued this any further at the time of writing but will return to this at a later time. In any event, it's unlikely that I'll need to use Channel B for measurements in the immediate future.

The horizontal/timebase adjustments were next on the list. Most of the adjustments were way over my head, so I left them as they were and simply adjusted VR5 to set the length of the trace to 11 divisions on the screen (the trace had been too long).

By this stage, the old oscilloscope was in reasonable working order (apart from Channel B) and it still worked correctly after standing idle for a few days. It's sufficient for the type of work I do and I'm reasonably happy with it, especially as it also came with a good supply of probes. Obviously, it should be completely calibrated, as it's probably not totally accurate.

However, I cannot justify the expense of having this done on such an old and basic unit and it's unlikely that I will require such accuracy anyway.

check it out. I also fitted an IEC socket to the aluminium chassis and reconnected the mains earth.

Suspecting that the hum may be due to lack of filtering in the power supply, I upgraded the 50µF 350V filter capacitor to 400µF 400V. The silicon diodes can handle a greater inrush current than the original 6V4 valve rectifier, so this modification wouldn't cause problems. In fact, the parallel 1N4007s will handle 2A whereas the current limit of the 6V4 is 800mA (exceeding this can destroy the valve).

Next, I replaced the 12AX7 and EL84 valves, switched it on and checked the voltages. The DC measurements were 200V on the B+ line and 180V on the anodes, while the AC ripple measured 45mV (which represented 0.03% hum) which isn't bad. That should solve it all, I smugly thought!

Unfortunately, when I plugged the unit into a 200W solid-state power amplifier feeding a pair of speakers, the dreaded hum was still there. It increased as the unit's volume control was advanced, indicating either hum pick-up from an external source or an earth loop somewhere.

So, it wasn't going to be that easy. I guessed this must have been the problem the owner spoke of, hence someone's last ditch attempt at "mosquito net" hum control. Well, at least there were no mosquitoes in the unit!

As stated, the reverb unit had been modified and I had previously noticed that the shielded cabling was unusually long and had been badly routed near the power transformer. I replaced all this cable with good-quality shielded cable and kept everything short and tidy and the hum decreased a little. I then plugged in a dynamic microphone, spoke into it and out came a reverberating voice!

I was very happy with the progress at that stage so I put everything back together, intending to leave it on test. The thing had not been designed for easy access and the reassembly process took over an hour.

Foot switch

There was also a foot-switch which plugged into the chassis using a 2.5mm jack. When the switch was closed, it bypassed the spring unit for normal voice. When the singer wants to add reverb during a song, he simply activates the switch to open the bypass circuit to get a predetermined amount of reverb.

The problem was that as soon as I plugged it in and activated the switch, a huge amount of hum emerged. That meant opening the unit up again to see if I could track this latest problem down.

Suspecting some sort of earth loop associated with the spring unit, I tried every possibility to remove it– such as disconnecting the screens on the various cables one at a time and earthing various points in a "star earthing" fashion. Unfortunately, despite my efforts, nothing brought the hum down.

Eventually, I tried a very short (100mm) foot-switch cable and that finally eliminated the hum. The usual cable was acting as a 3-metre 50Hz hum antenna connected directly to the triode control grid and it was doing this very efficiently.

When I phoned my friend, he was adamant that the foot-switch was compulsory for gigs and must be retained. What was I to do? I had already spent heaps of time on the unit and a 100mm cable was too short. And then it hit me – why not use a relay to switch the unit? By fitting the relay into the chassis, I could keep the contact leads short and also bypass the lead from the foot-switch close to the chassis.

It was a good idea but just where do you get a low voltage to activate a relay in a valve circuit? Using a DMM, I discovered that there was about 5V across the 50Ω cathode bias resistor on the EL84 which I could possibly use. I then fitted a small 5V relay with a 500Ω coil to the unit and hooked up the foot-switch to activate it.

It all worked perfectly. However, due to my over-active foot, the foot-switch itself then decided to give up the ghost – Pandora again! I replaced it with a 250VAC mains-rated switch and a twin-core cable, just to be safe.

Performance testing

Out of interest, I checked out the repaired reverb on a newly acquired Audio Precision test set. With reverb off, the THD + N (total harmonic distortion plus noise) was around 2% at 1kHz (20Hz-22kHz) and 3% with reverb on. The frequency response curve looked like a semi-circle, peaking at about 700Hz which is fine for voice presence and overall not too bad for such an old amplifier from the 1960s.

I printed out the plots so that the owner could keep them with the reverb unit for reference.

Amazingly, the added relay had no effect on the gain, distortion or frequency response that I could measure. It just clicked and a slight "boinnng" was heard as the springs switched in, so the user knows that the reverb is "on".

When I returned the unit to its owner, I showed him the hard copies of the measurements I made. When I told of the 3% total harmonic distortion, his reply was "beauty!" – musicians just love their distortion! SC

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Issue: January 2016

Back to work deals!

Jump into 2016 with all the new gear for your new year.

NEW!
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A 0287

Lithium/NiMH Cell Charger

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S 9437

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NEW!

Add-on	Part	ARP
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M 8880

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SAVE 15%
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SAVE 15%
$90
M 8534 6/12V 4.5A 7 Stage
$178
M 8536 12V 10A 10 Stage

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T 5020A
Tools not included.

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C 7185B

$1099
SAVE $300

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Handheld UHF Mic	C 7193B	$229
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Hundreds sold to schools, institutions & wedding celebrants

Balanced mic input • Speaker stand recess • Weighs just 12kg! • CD/MP3 player

16 Channel 520MHz UHF Wireless Mic Systems

A complete wireless microphone system with your choice of handheld or beltpack mic. Offers wireless freedom when on stage. • Plugs into existing PA systems • Crisp vocal reproduction • Ideal for clubs, restaurants, places of worship & wedding ceremonies. Up to 70m range.

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Address Large Crowds With Ease

An all in one portable PA unit with amp that sets up in just seconds - no expertise required. Just plug into 240V power, switch it on and connect a mic, USB playback makes it easy to play your favourite tunes. Great for clubs, sports events, fetes, carnivals and bingo nights!

A 2620
SAVE 18%
$29

Portable Mini Audio Mixer

Powered by 9V battery or plugpack (M 9237A $17.95) this tiny mixer is perfect for small productions. Mixes four 6.35mm mics.

SAVE $40
$109
A 1980

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Looking to rally a crowd? Nothing works better than a loud hailer! Requires 6 x C batteries

SAVE 22%
$35
C 0383

Virtually indestructible!

Drop Proof Microphone

Tough grill resists damage, even when dropped on hard floors. Ideal for clubs & schools. Includes 5m 3 pin XLR lead.

SAVE $40
$109
C 0388

The best mic in our range.

Pro Grade Dynamic Mic

A 'no compromise' mic fitted with a high end professional unidirectional dynamic insert for excellent speech reproduction.

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C 5058

Superb sound at an affordable price!

Microlab® SOLO-1C Active Bookshelf Speakers

Unbelieveable sound for a bookshelf system under $150. Perfect for music, gaming & TV. Requires no external amplifier. Hear a demo in-store! Also see the 'bigger brother' SOLO-6C C 5060 $199.

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A 2691A

Opus One® 2x100W Stereo Amplifier Receiver

Expand your home audio system to the study or entertainment area. Features six stereo inputs, AM/FM tuner and A/B speaker selection. Includes remote.

NEW!
$129
A 1100

FM tuner & USB/SD card playback

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Wireless audio streaming from your smartphone, direct to the wall controller. 2x15W RMS stereo amplifier built in, great way to install speakers in your home.

SAVE 14%
$26
A 0977A

With Infra-Red Learning

Jumbo 4 In 1 Remote Control

• Great for the kids! • Each button is about the size of a 20c coin! • Pre-programmed with 1000's of codes, plus IR learning • Requires 2xAA batteries • Size: 284 x 128mm.

Mini Bluetooth® Speaker

With NFC pairing. Sounds great! Hands-free phone functions.

REDUCED!
$19.95
D 2037

A 1171A
SAVE 25%
$44

Infra-Red Extender Kit

Includes hub, two dual eye emitters, target & plugpack. Foxtel compatible. Easy to set up!

Tool up for the new year...

$549 SAVE $50

T 1287

4 popular tips included.

Micron® 1000W Hot Air SMD Re-Work Station

Fantastic commercial grade unit - intro special, save $50.

Provides a quick and easy way to rework boards fitted with surface mount devices, even in RoHS products. It works by blowing 1000 watts of heated air onto the board your are working on, melting the solder on the SMD pads.

70L per minute air pump | **Four blower tips** | **2 year warranty**

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T 2418

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An excellent multi purpose soldering iron for service technicians, schools, engineers, R&D, production work etc. Japanese long life ceramic element. 200°-480°C. 0.8mm tip. **2 year warranty.**

2 Year Warranty.

$199 SAVE $80

Q 1536

High Accuracy 2.7GHz Frequency Counter

Covering a range of 10Hz to 2.7GHz in two ranges: 10Hz to 100MHz and 100MHz to 2.7GHz. Ideal for servicing and calibrating RF equipment, radio mics, CBs & transceivers. Period, frequency, pulse count (totalise) functions. x20 input.

$145 SAVE $54

M 8263 9-15V 30A

$119 SAVE $40

M 8261 9-15V 20A

Analog Lab Power Supplies

These compact, fan cooled, switchmode power supplies deliver up to a huge 30A regulated output, adjustable between 9 and 15V. Plus fixed 13.8V setting. Low noise design. 85% efficient. 155x70x205mm.

$99 NEW!

Q 1341

Network Cable Tracer

Combines a cable tracer and tester in one unit. Injects an audible signal down the line to make it easy to find the specific leads. Requires 3 x AA and 1 x 9V batteries.

Q 1133A

$40 SAVE 14%

Handy Auto Ranging DMM

Simplicity & functionality in one compact test device. 10A DC current. 1Hz-30MHz counter. Includes test leads & temp probe. Great for students!

$99 SAVE $20

Q 1264

Fine Tune Your Sound System

This SPL meter measures up to 130dB (1.5dB accuracy). Used widely in the audio industry for ensuring sound levels remain legal. Includes 9V battery.

Jumbo easy read display!

Q 1067

$65 SAVE 12%

Precise 28 Range DMM

Includes temperature probe at no extra cost! Excellent for the service technicians or enthusiast. Massive 20A rating AC/DC to 1000V.

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Iroda® 125W Portable Gas Tool Kit

Totally wireless operation - No need to run extension leads! Super tough design will last for years. Easy to light, one-click piezo ignition. High reliability long life tips. Blow torch & soldering iron in one. 2 year warranty. Includes hot air tip, heat deflector, additional gas cartridge, solder, sponge and hard carry case.

SAVE $24 $95 T 2630 Iron Only

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T 2420

Quality 20W Mains Soldering Iron

• High efficiency heater • Thermally balanced nichrome heating element. • Burn proof lead • Includes iron clad, chrome plated 1.6mm long life tip • 370°C fixed temp • Includes stand

Top Toolbox Essentials!

SAVE 19% $20

T 2173

Precision Driver Kit

An aluminium driver with rotating ferrule top for easy servicing of precision high tech devices. Includes 70mm extension bar and 28 x 4mm hex bits. See web for full list of bits.

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T 1450

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T 1460 Magnifier

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T 1460

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A must have for the soldering enthusiast! Great for working on boards up to 200 x 140mm in size. Heavy base and rubber feet ensure a solid working surface.

Great for servicing

T 2171

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A 22pc ratchet set designed for working in tight spaces. Fits in the palm of your hand, or use with the optional wrench handle. Includes driver tips and sockets.

Huge new range for makers!

Electrocardiogram Arduino UNO Shield Kit

(SC Oct' 2015) An easy-to-build Arduino project which will let you take your own electrocardiogram (ECG) and display it on a laptop PC. The software lets you read, display, save and print the electrical waveform generated by your heart – or anyone elses. Requires Arduino UNO.

$59.95 NEW KIT!

K 2523

NEW KIT!

NEW KIT!

K 9350

$129 TOP VALUE!

Control access by the press of a finger.

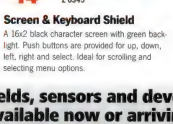
(SC Nov' 2015) The Fingerprint Access Controller stores and recognises up to 20 prints and provides quick access for authorised people. An indoor control-panel allows easy setup of the system, while the fingerprint reader is mounted in the supplied wall-plate.

NEW!

Z 6349 $24.95

ATMega328P Lilypad Board

Great for moving UNO based designs & code into e-textile projects. Can be used with Z 6368 LED sequins ($4.95 5pk).



NEW!

$14.95 Z 6345

Screen & Keyboard Shield

A 16x2 black character screen with green backlight. Push buttons are provided for up, down, left, right and select. Ideal for scrolling and selecting menu options.

NEW!

Z 6339 $21.95

DC-DC Boost Module

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Over 70 new shields, sensors and development boards - many are available now or arriving early 2016!

NEW!

Z 6346 $24.95

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The 'lilypad' form factor allows easy building of sewable electronics and e-textile projects. Can be used with Z 6368 LED sequins ($4.95 5pk).

NEW!

$24.95 Z 6343

L298 H-Bridge Motor Shield

Uses an L298 H-Bridge designed to drive relays, solenoids, DC and stepping motors. It can also drive two independent DC motors. Standard Arduino shield dimensions. 5V input.

NEW!

$19.95 Z 6337

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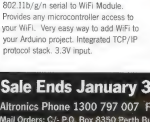

NEW!

$7.95 Z 6355

3.3 or 5V output!

Breadboard Power Supply

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NEW!

$14.95 Z 6348

Nokia 5110 LCD Screen

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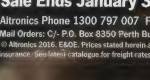

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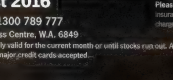

NEW!

$39.95 Z 6342

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NEW!

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Who said the Australian Electronics Industry was Dead?

by Ross Tester

Versatile Technology - an Aussie Innovator

It started out as an invitation to see a model tank. Not just any model tank, but a 1/5-scale fully operational German "Tiger" Tank. But while we were there, we had a look at the company Gerard Dean, the tank's creator, had set up.

More on the tank anon – but our visit to Versatile Technology, in Melbourne's eastern suburbs, proved to us that not all Australian technology has disappeared offshore (even if 97% of their products do, go offshore that is!).

What's in a can?

When you pop open a can of beer or soft drink, do you ever think about the technology that goes into that can? No, of course you don't: you just want to enjoy the contents then throw away (woops, recycle) the can when it's empty.

Most companies have mission statements with motherhood, feel-good comments. Here's Versatile Technology's, displayed for all to see as you walk in the front door!

But there is an enormous amount of precision engineering and manufacturing in that can. What happens, for example, if the contents (which are usually under quite high pressure) find a weakness in the can and decide that the outside world is a better place to be?

For example, only recently, a friend of mine emailed me a picture of the interior of her car following just such an incident with a can of Coke on a rather warm day.

As you no doubt realise, a car's cabin temperature can easily reach 60-70° and more, sitting in the sun even on a relatively cool day (see RACQ report, February 2009).

If the can is in direct sunlight (as this one was) then it can actually get hot enough to burn you.

Cans have several safety mecha-

nisms built in to prevent them exploding – and these are exactly the areas that Versatile Technology manufactures machines to test.

For example, that "dimple" or concave in the base of the can is not there to save the beverage manufacturer some beverage. It's designed to expand as the pressure inside the can exceeds a certain safety margin – we've all seen cans that have been frozen, for instance, where the concave dimple has "popped" out and become convex. The can will topple over if this happens – but that's a few orders of magnitude better than having the can explode. Exactly the same thing happens if the can is overheated.

One of Versatile's gauges seals the can then pumps air into it until it pops, in order to prove that the can is within spec.

Then there's the thickness of the can itself – is it uniform; does it have any thin spots which may allow it to deform or explode? Here they measure the thickness with a margin for error of just 0.5 microns. How thick is that? Blonde hair is about 10-30 microns in diameter! (Black hair is even thicker).

How about the join between the can itself and the lid (bet you never thought that it was a two-part assembly, did you)?

And there's the opening tab – it's purposely designed as a weak point to allow you to get at the contents without an opener. But if it's too weak. . .

Incidentally, remember those old "ring pulls" which used to cause many a broken fingernail when removing, or cut feet when carelessly disposed of at the beach, park, etc? (Or which were/are the treasure hunter's nightmare, causing metal detectors to go crazy!)

Well, Versatile Technology showed me some brand new cans with that type of opening – it turns out there are certain cultures in Asia and the Middle East which demand them, instead of the stay-attached-to-the-can type we're all used to these days.

All of these parameters – and many more – are what Versatile Technology manufacture testing equipment to, well, test. Incidentally, they use the industry moniker "gauges" for the equipment they build.

They don't manufacture the cans themselves – they manufacture a broad range of test equipment which is sold around the world to corporations that do manufacture cans. Billions of cans!

Versatile's Gerard Dean talking to a potential customer at last year's METPACK show in Essen, Germany. He came away with a briefcase full of new business!

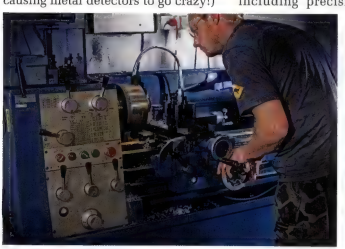
In more recent times, they've also started making gauges to test other containers, such as PET soft drink bottles and even steel cans. The principles are the same but different tests require a completely different approach.

The company

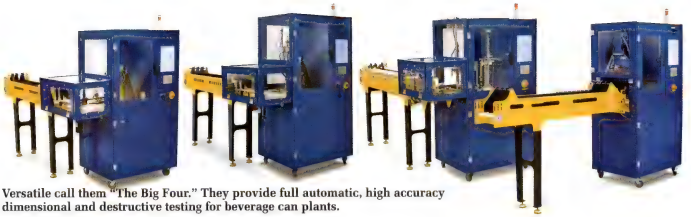
Long before Versatile Technology was established, Gerard Dean set up a business making small custom-designed measurement instruments, including precision rotary torque transducers, for a company that supplied Ford, Holden etc.

It was a small show and most of the work was done in Dean's back shed. Fast-forward 35 years, when in 1990 Versatile Technology was formed to build custom measurement systems for the Australian industrial market, predominately in the automotive area.

It was tough and they drained the investors' cash pretty fast. The jobs in the automotive area had tight margins and other jobs were very small.



What Versatile Technology needs, they make in their own machine shop. This gives them outstanding quality control, while keeping production costs to a minimum.



Versatile call them "The Big Four." They provide full automatic, high accuracy dimensional and destructive testing for beverage can plants.

A bit of luck!

Then, luck came Versatile's way. A shareholder had a mate who worked for a beverage can maker, who complained about an American gauge that measured the buckle strength on the bottom of the can. It constantly broke and getting spare parts and service was very difficult.

Versatile took on the job and one of their original employees, Peter Treble, invented a new sealing system to test the buckle. They incorporated his idea into the new gauge – and the customer loved it and rewarded them with extra orders.

Gerard, along with his wife Annie, took the gauge to the Metpack trade show in Essen, Germany. Within an hour of opening, a German company said they would order eight gauges.

Over the next few years "Versatile" gradually became less and less "versatile" – despite retaining the name – and more and more focussed on the can industry. By 1995 exports exceeded local production and has increased ever since. In fact, last year they exported over 99% of production to the USA, Europe, Japan, China, South America, Middle East and Asia.

Last year they manufactured more automatic gauges for canmakers than any other supplier worldwide and their "other" gauge market is constantly growing.

Infectious enthusiasm

The first thing I noted about Versatile was the incredible infectious enthusiasm (some might say eccentricity?) of Gerard Dean. It's an enthusiasm passed on to all staff, who were almost passionately demonstrating what their particular gauges would do.

I confess that some of it I didn't quite understand – but that didn't stop the "Versatilers" trying to explain it all to me.

The second thing I noted was the age of the staff. Gerard tends to hire specialist staff straight out of University "before they've had a chance to be corrupted by the way others work" and most of the staff appear to be very young – but at the same time very professional. The company doesn't have a high turnover so there are several who have "grown up" with the Versatile way. Most of the hires are to expand the operation, not to replace someone.

It's a somewhat "quirky" company, witnessed as you walk in the front door by the company mission statement... "Total War", it reads! Another piece of evidence: all of the equipment the company makes is given a name – almost universally that of a WWII German 'plane, tank or other battle equipment. Why? "Why not?" asks Gerard! "I told you we were different!"

The FE056 Front End Gauge scans and graphs an aluminium beverage can wall. Measuring a floppy 90 micron thick can wall made to a manufacturing tolerance of ±5 microns pushes measurement gauges to the limit. The gauge resolves to 0.1 micron and must have no more than 0.5 micron error over 100 readings.

International reputation

Over the years, Versatile has developed considerable – and highly specialised – expertise in the testing and gauging of metal packaging, to the point where in 2014 the "little Aussie company" achieved the unthinkable – they became the world's leader in the industry, exporting equipment to names that probably mean little to most people, but if you're in the beverage industry, will be very familiar.

A point of clarification: very few (if any) beverage packagers manufacture their own containers (or "closures"). Instead, they rely on international companies such as Ball, Rexam, Crown, Ardagh, UCC Japan, KJM, Helvetia, Silgan and many more around the globe.

And the chance are that those com-

While the majority of their equipment is intended for cans (aluminium and steel) they also have the gear to test other closures, such as PET soft drink bottles.

panies have one, or ten, or many more Australian testing and gauging machines from Versatile. They've recently signed huge contracts for "greenfield" manufacturing sites being built for local packaging manufacturers in many countries, from the heat of the middle east to the freeze of northern America.

In fact, one of our photos shows several completed and tested gauges being prepared for delivery to a can manufacturer in Minnesota, USA, in the next six weeks – and one of Versatile's engineers will be on hand for installation and commissioning. Let me tell you, even for staff used to Melbourne's four-seasons-in-one-day, northern Minnesota in January is not a fun place to be!

The next gauge to be installed is just as likely to be in the heat of the middle east, or deepest, darkest Africa, or . . .

Faultless here, but not there!

One of the other engineers told me about a machine they'd installed in the USA after design, building and (absolutely flawless) testing in Melbourne. The only problem was it wasn't exactly flawless, in fact exactly the opposite. Every time it was started up the computer crashed!

After much weeping and wailing and gnashing of teeth, the engineer in charge was working on the problem late at night, long after the factory had shut down and most of the lights were off.

It was in this environment that he noticed a spark out of the corner of his eye as an empty can was loaded into the machine for testing.

Long story short, the location was one of the driest on the planet, with consistently 10-20% maximum humidity. As the cans were moving along the line, they were picking up a static charge and it was this, arcing to the mechanism, which caused the problem. A simple earthing strap solved the problem and it has performed perfectly ever since!

Another engineer was installing a machine in a can factory in Lagos, Nigeria, when the car he was driving, even with an armed bodyguard, was hijacked by locals with their "tools of trade", AK-47s. Did it phase him? Not on your life: he simply obtained new transport and continued on with the job.

In house, from conception to finish

Much of the gauging and testing equipment is developed to specific customers' requirements. Their SGU, or Special Gauges Unit, will build a tailored automatic unit to the customer's brief (or better than it!) and guarantee the outcome, in a no-surprises, all inclusive package.

Again a team of dedicated engineers handle all aspects, from initial discussions and job briefing, through confidentiality agreements, quotations, design, building, testing, etc – right through to installation, commissioning and even operator training.

"Given the enormous amount of design and effort required, we don't make any money on the first unit," said Gerard. "But we're so confident they will find our gauges so much better than anything else they've used, they'll come back with additional orders. It happens time and time again, even in such a limited market as we serve."

Indeed, one European can manufacturer has come back and ordered five new gauges. They have a sixth one, of local manufacture (because they had to due to political pressure!) but it generally sits unused while the Versatile equipment provides them with so much more data – and with guaranteed accuracy – that they don't need it!

Some examples of special projects include destructive gauges for crush, buckle and distortion applications, automatic "pop and tear" or buckle gauges testing container integrity, on-gauge camera capability with extremely high precision measurement incorporated, and much more.

The Tester Testing – the author reviews final trials on equipment destined for a European customer.

But they also develop generic equipment to suit a worldwide market. Their dedicated team of mechanical, electrical and electronic engineers start with the concept, producing almost everything in house (or minimal subcontracting where required).

They design the process required, then design the equipment and the electronics required to achieve it. From original printed circuit boards and computer code, to the mechanical assemblies, pneumatics and measurement equipment then through to the large housings and finally, the data analysis and reporting systems, it all comes out of the factory in South Oakleigh.

Speaking of the factory, they must be doing something right, as Gerard Dean has recently purchased the adjoining factory, doubling their floor space and enabling significantly more design and production output.

Huge R&D

Most organisations think they are doing pretty well if they invest 5% of turnover in research and development. 10% is almost unheard of.

Versatile invest 20% – over a million dollars a year – to keep well ahead of the game; showing some of the biggest names in the field the way things should be done.

An example is their unique custom-designed V2 embedded processor, which, in conjunction with similarly custom-designed hardware, tightly integrates measurement, control, the user interface and data analysis/output on every piece of equipment.

They proudly state that their equipment is not based on any existing computer platform – Windows, PC or otherwise (not even the games controller they've found in some opposition equipment!).

In aluminium beverage cans Versatile's scanning automatics are the acknowledged market leader. In DWI (Drawn Wall and Ironed) beaded steel cans, Versatile automatics dominate the market.

Guaranteed performance

Most test equipment is manually operated, requiring a complete stop and component change for different-sized enclosures, Versatile's is not only fully automatic but can make changes "on the fly". Some of the equipment is stand-alone but they have the capability of integrating into an existing production line for continual sampling and checking.

Versatile will not ship a unit until it is completely calibrated, traceable to NATA/NIST standards. They told me that theirs is far ahead of most "somewhat" competitive equipment. "Most equipment is calibrated to five microns (about the thickness of a human hair)," he said. "Ours is calibrated to one micron and our design objective is 0.5 microns."

All equipment is also Gauge Safety Tested and shipped with its own safety test record and in these days of OH&S making increasingly difficult requirements, its own Risk Assessment.

Word of mouth is the best advertising

Versatile Technology does very little advertising. Their marketing effort is aimed more towards trade shows and, being almost universally held overseas, that's where they place some of their innovative equipment.

They earned the ire of a recent European show organiser (and other exhibitors) when they rather cheekily hung a very large banner near the entrance to the show inviting people to their booth.

They got away with it by telling the organisers "that's the way we do things in Australia!"

Gerard Dean told me "we are different to other companies. We're the young upstarts from Down Under and we don't play by the same rules as our

It mightn't mean much to you or I but if you're a can manufacturer, this poster could be a godsend! It's just one of the many Versatile Technology gauges.

opposition. We're better!"

"For many companies, gauging and measurement equipment is just a small part of their product line and operation and they don't give it the support that is necessary. It is Versatile's only business and we go out of our way to not only design perfection into our products but support them to the hilt."

"When we get the opportunity to demonstrate what our gear will do versus what they either have been used to or have had demonstrated by others, their jaws hit the ground. Most opposition equipment is designed to give either the barest statistics that management want or the parameters that production want. Ours gives both, with reports that boards can understand, analyses of what is being produced and how they can ensure the absolute maximum in production levels at the highest possible standards."

"We're not being boastful, but ours is the best in the world bar none. OK, we are being just a little bit boastful!"

Copies and (imperfect) clones

One of the difficulties Versatile Technology faces on a regular basis is other organisations (and almost universally out of Asia) trying to produce a competitive machine by the tried-and-true method of copying everything in the Versatile machine.

Invariably, this has failed – partly because of the steps that Versatile go to protecting their code, hardware and so on (even though patented in mostcases, that doesn't stop rip-offs) but mainly because of the company's reputation on the world stage.

They've even gone to the extent of putting in some "blind leads" from time to time (extremely important bits that do . . . nothing!) and when they see one of the copies at a trade show, sure enough, the blind lead is built right in – still doing nothing!

Potential customers are quick to see the imperfections in opposition equipment (and if not, Versatile Technology have no qualms in pointing it out!). The end result is that customers come back to Versatile, even if it is more expensive.

"If you want perfection, you need to spend a little more," they say. *sc*

Do you know of a successful, innovative Australian (or NZ) electronics company whose story deserves to be told? Let us know! email editor@siliconchip.com.au

About that tank!

Gerard Dean's "Der Tiger", a one-fifth scale, fully operational WWII Tiger Tank "took ten minutes to dream up and ten years to design, build and get running."

That includes laser-cutting a steel chassis that needed a fork-lift to unload from the truck (just the chassis!) and realising that aluminium would be much lighter . . . to finding (after the event) that aluminium for laser cutting was not really suitable for welding . . . to designing and crafting every component in the Tiger's motor, running gear, control systems and even the operating cannon – then putting it all together. That is when a lot of the fun started, getting all the "bits" to work with each other.

Even the custom-built 16-channel radio control system recreates the Tiger's 10WSc radio and driver's controls.

But in the end, the masterpiece faithfully reproduced (as much as possible) the original, much-feared Wehrmacht war machine. In 2013, it took out the Gold Medal in the Internal Combustion Engine category at the Model Engineering exhibition, England.

Hand-made motor(s)

It's powered by a home-designed and built 150cc V12 petrol engine (the original Tiger had a slightly larger 21 litre Maybach diesel engine), an eight-speed gearbox (same as the original) and the finished tank weighs in at 250kg – hefty enough in its own right (imagine what it would have been in steel!) compared to the original's 58 tonnes.

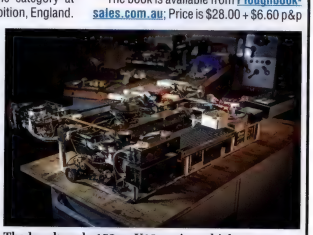
The V12 is not the first motor built "from the ground up" by Dean; he's constructed many over the years and even had a flathead V8 before it was pointed out that the Tiger had a V12 – so Dean then set about designing and building the V12.

The motor (and its add-ons) has not been without its problems, most particularly when Der Tiger was sent to England and several key components failed. But each time, Dean has re-designed, re-made and re-installed to keep Der Tiger moving.

The book

Gerard Dean kept a detailed record of the trials and tribulations building Der Tiger, with a 124-page book simply called "Der Tiger" the end result. It's comprehensively illustrated with diagrams, 3-D generated illustrations, block diagrams and so on. We're not saying that anyone could pick up a copy of "Der Tiger" and build a 1/5 scale Tiger Tank . . . but at least you'll know what you're up against!

The book is available from **Ploughbook-sales.com.au**; Price is $28.00 + $6.60 p&p



The hand-made 150cc, V12 engine which powers Der Tiger.

Vintage Radio

By Ian Batty

Sony's TR-63 Shirt-pocket Transistor Radio

Released in December 1957, the TR-63 was Sony's first pocket-size transistor radio. It's a 6-transistor superhet design with some interesting design features, including the use of Sony-manufactured NPN transistors in the circuit.

Masaru Ibuka served with the Imperial Navy Wartime Research Committee during World War 2, leaving in 1946 to join Akio Morita to form Tokyo Tsushin Kogyo Kabushiki Kaisha, "Totsuko". Morita, a physics graduate, had served alongside Ibuka in the Research Committee, and their friendship laid the foundations for the international powerhouse we now know simply as Sony.

Tokyo Tsushin Kogyo's first product, a rice cooker, says a lot about the company. Japan had suffered massive destruction during World War 2 due to bombing and people needed utensils to cook their staple food, which was rice.

So a rice cooker that simply used two insulated metal plates ingeniously met a vital need. That combination of opportunity and ingenuity set the model for Sony's future. Their first radio-related product, a shortwave converter for broadcast-only radios, helped open Japanese society up to the wider world. Tape recorders subsequently became a major product line and were widely used in schools and courts.

Following Ibuka's visionary 1952 trip to the USA to sign a licence with Western Electric, Sony acquired patent rights for the transistor and subsequently began manufacturing portable radios in 1955.

Early difficulties

Sony preferred NPN transistors because of their better high-frequency response but were initially unable to produce working examples.

NPN devices exploit the fact that electrons move more quickly than holes, ie, they have higher mobility. This is critical in the base region and it's here that low mobility has the most effect on high-frequency performance. The problem is that NPN devices were more difficult to manufacture using germanium feedstock.

Knowing that, theoretically, NPN transistors were the way to go, Sony saw experiment after experiment fail to demonstrate useful performance. After much discussion, Sony's research laboratory head, Mikato Kikuchi, suggested dropping Bells' preferred doping agent, indium, and substituting phosphorus instead. When that didn't work, Morita called for "more doping"!

It soon paid off and Sony were able to produce the transistors used in their first solid-state radios. Their TR-55 model, released in 1955, is now a rarity and the last one to be listed online some years ago had a price tag of $US1500.

One can only imagine the energy invested by Sony to leap from Ibuka's licensing agreement to a marketable transistor radio in just three years. It's also possible to imagine their frustration at being pipped at the post by Regency's TR-1 transistor radio (SILICON CHIP, April 2013), which was released less than six months before.

Sony's first "pocket-size" transistor radio, the TR-63, was subsequently released in December 1957. It was, however, reputed to be too big for a standard shirt pocket and the story goes

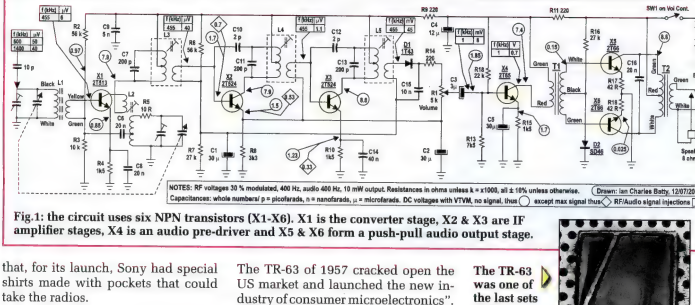


Fig.1: the circuit uses six NPN transistors (X1-X6). X1 is the converter stage, X2 & X3 are IF amplifier stages, X4 is an audio pre-driver and X5 & X6 form a push-pull audio output stage.

that, for its launch, Sony had special shirts made with pockets that could take the radios.

Sony's TR-63

At first glance, Sony's TR-63 is a pretty conventional 6-transistor set, with three transistors used in the RF/IF section and the other three in the audio amplifier stage. All the transistors were manufactured by Sony and they are all NPN types.

As noted above, Sony preferred NPN transistors because of their better high-frequency performance. My set was kitted out with the rectangular TO-22 can transistors, the same style as used by Texas Instruments in the Regency TR-1.

Sony's hand-held TR-63 was offered in lemon, green, red and black. It used a miniature, solid-dielectric "polyvaricon" for the tuning capacitor and it also required a new battery design that became the iconic "PP9" and set the standard for transistor radios.

As a piece of portable electronics, the TR-63 is a winner. It's small enough to pop into my shirt pocket, something which couldn't be said for the TR-1 and other early sets from Raytheon, GE and Zenith. It also fits the hand better, the rounded edges giving it an easier feel than many others.

What's more, the TR-63 is a good performer. It's also one of Sony's last sets with the old "lighting bolt" logo that was superseded by the "Roman text" logo we're more familiar with. As well, it carries the "Totsuko" stamp on the rear cover.

But it's not just an elegant personal radio. It's described thus in Schiffer's *The Portable Radio in American Life*: ". . . (Sony) was not first, but its transistor radio was the most successful. The TR-63 of 1957 cracked open the US market and launched the new industry of consumer microelectronics".

With total exports to the US alone of about 100,000, the TR-63 was a true runaway success.

The accompanying photo of the TR-63 shows the red "Conelrad" marks on the dial at 640kHz and 1240kHz, as required by US law at that time. So what was "Conelrad"?

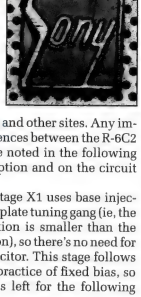
Basically, this acronym stood for CONtrol of ELectronic RADiation and was set up in the US in 1951 to provide emergency radio warnings to the public during the Cold War. If an alert was received, most radio stations were required to cease transmission, while each remaining station was to move to either 640kHz or 1240kHz. They would transmit for several minutes and then go off the air, and another station would take over on the same frequency in a "round robin" chain, the idea being to confuse enemy aircraft that might be navigating using radio direction finding.

By law, radio sets manufactured between 1953 and 1963 had the required frequencies marked by the triangle-in-circle (CD Mark) symbol of Civil Defence, so that the set could be quickly tuned to either 640kHz or 1240kHz.

Circuit details

Several circuit variations exist (denoted by the circuit board number) and these are based on either the early production R-6C1 sets or the later R-6C2 version. The circuit shown here (Fig.1) is based on my R-6C2 and is also the version shown in an H. W. Sams Photofact.

In addition, the schematics for both versions are available on www.radiomuseum.org and other sites. Any important differences between the R-6C2 and R-6C1 are noted in the following circuit description and on the circuit diagram.



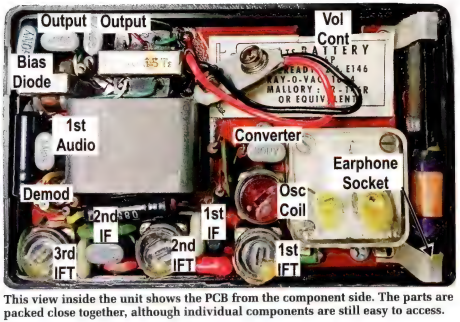
The TR-63 was one of the last sets with Sony's old "lighting bolt" logo.

Converter stage X1 uses base injection and a cut-plate tuning gang (ie, the oscillator section is smaller than the antenna section), so there's no need for a padder capacitor. This stage follows the common practice of fixed bias, so gain control is left for the following IF section.

The first IF transformer (*L3*) uses a tapped, tuned primary and an untapped secondary and this feeds the first IF amplifier stage which is based on X2. This stage is gain-controlled by the DC voltage fed back from the demodulator. Unusually, X2's bias is derived from a voltage divider (R6 & R7). While this would usually provide constant bias and thus constant gain, R6 and R7 have higher values than usual and this allows "relaxed" control of X2's base voltage.

Basically, this allows the AGC circuit to control X2's gain but with less effect than in the circuits commonly used in other sets.

The second IF amplifier is based on transistor X3 and this gets its bias from X2's emitter, so AGC is applied to both IF stages to give effective control. Note



This view inside the unit shows the PCB from the component side. The parts are packed close together, although individual components are still easy to access.

also that the AGC return from the demodulator is fed to X2's emitter, again an unusual configuration. Commonly, the AGC return is to ground, which means that the IF amplifier's emitter resistor forms a negative feedback circuit for the AGC control voltage. This helps to "soften" the very strong "sharp cut-off" AGC action that would otherwise occur if the control voltage were simply applied between base and emitter.

In operation, the R-6C2 version of the TR-63 applies a moderate amount of AGC to both IF stages and directly applies AGC between X2's base and emitter. By contrast, the 6C1 uses a conventional series bias circuit for X2 but still has the AGC voltage applied directly between base and emitter.

Transistor X2's collector feeds the tapped, tuned primary of the second IF transformer (L4). As shown, L4's centre tap connects directly to the supply rail, while the top of the primary connects to neutralising capacitor C10 (2pF). L4's untapped, untuned secondary feeds the base of the second IF amplifier (X3).

As mentioned, X3 in the R-6C2 version gets its bias from X2's emitter. This means that the AGC controls both IF stages. By contrast, the R-6C1 version simply uses fixed voltage-divider bias for X3 and so its resistance to overload isn't as good.

The third IF transformer (L5) feeds demodulator D1. In the R-6C2 circuit, the AGC return is via R14 and volume control R1 to X2's emitter (and X3's base). Alternatively, in the R-6C1, the AGC return goes to the emitter of X2 and also to the emitter of X4, the audio driver stage. The AGC control voltage itself is derived from D1's anode and is series-fed back through the third IF transformer's secondary to X2's base (both versions).

Audio amplifier

The recovered audio from demodulator D1 is fed to transistor X4 via the volume control and capacitor C3. This audio driver uses combination bias. The R-6C1 circuit (unusually) connects X4's emitter to X2's emitter, so that X4's emitter voltage varies somewhat with AGC action. The R-6C2 circuit omits this connection, giving a constant voltage on X4's emitter.

X4 feeds driver transformer T1's primary. The R-6C1's circuit shunts this winding with a treble-cut capacitor but the R-6C2 omits this component. Transformer T1's centre-tapped secondary then drives a push-pull Class-B output stage based on transistors X5 & X6. This stage uses bias diode D2, which is described as a "varistor".

In reality, this diode is the collector-base junction of a transistor. It's used here as a temperature-sensitive bias supply that matches the base-emitter characteristics of the output transistors. It basically provides thermal compensation for the push-pull output stage and is a mark of good design by Sony. Any number of other manufacturers were still struggling with less-effective fixed/adjustable bias schemes or complex thermistor-compensated bias circuits.

X5 & X6 drive output transformer T2 which is shunted by a top-cut capacitor in both versions. T2 in turn drives a 3.5-inch (89mm) internal speaker via an earphone socket. The earphone socket disconnects the loudspeaker when an earphone is plugged in.

Initial tests

This was another easy set when it came to restoration, at least as far as its appearance was concerned. A good clean and a light polish were all that were needed to restore it to near-new condition. A quick check of the earphone socket revealed that it was OK and I gave the volume control a light spray of contact cleaner to ensure trouble-free operation.

I then applied power and checked the supply current. This was as expected and there was some noise from the set when the volume control was operated. This was then followed by wild oscillation on all stations and then silence.

Replacing C1 and C2 (both 30µF electrolytics) cured the oscillation at those times when the set was working. Unfortunately, there were still times when it refused to work.

I soon discovered that when the set stopped working, X2's base and emitter voltages were way too low. The bias circuit itself checked out OK and the problem turned out to be a faulty transistor.

In operation, X2's internal collector connection was going intermittently open circuit. Normally, the bias circuit supplies the base current and multiplying this by the transistor's current gain produces the emitter current and thus the intended voltage across the emitter resistor.

However, if the collector connection goes open circuit, the base-emitter junction behaves as a simple forward-biased diode. If that happens, the emitter resistor is pretty much shunted across the bottom resistor in the bias network, resulting in very low base and emitter voltages.

The most common causes for open collector connections are open-circuit loads (especially inductors and transformers), bad solder joints and bad socket connections. In this case, the set came good after a few sharp taps on transistor X2, indicating that its collector was going open circuit inside the can (probably between the collector lead wire and the germanium slice).

I needed a replacement transistor

and a search through my trusty junkbox soon yielded a Sony 2SC73 (a germanium NPN). This transistor has a bandwidth (Ft) of 8MHz as opposed to the 2T524's 2.5MHz, so I expected to get more gain with the new transistor. This was subsequently proven to be correct.

During my initial tests, I found that the audio section needed many tens of millivolts to produce an output, so electrolytics C3 & C5 were replaced. This immediately brought the audio gain up to expectations.

As an aside, using electrolytic capacitors for IF/RF bypassing is now considered poor design and as noted above, the set's initial violent oscillation problems were cured by replacing C1 & C2. Electrolytics exhibit considerable series resistance and inductance, restricting their effectiveness to audio frequencies. Common practice would now be to shunt C1 & C2 with disc ceramic capacitors to ensure effective RF bypassing.

How good is it?

Looking at the circuit and its build quality, the TR-63 appears to be a well-engineered set but how well does it perform? To find out, I decided to make some basic sensitivity and distortion measurements.

As shown on the circuit, a 10pF capacitor is connected to the top of the ferrite rod. As this set uses base injection for the local oscillator, connecting my signal generator to X1's base stopped it dead for broadcast-band signals. I was able to get IF sensitivity readings but no RF readings.

The simplest way around this was to connect the generator via the 10pF capacitor. This gives reliable results but it doesn't give the actual signal voltage required at the converter's base connection, as would usually be specified. The set did, however, respond correctly to a direct IF injection, so I've given this result as it's a better guide to the set's sensitivity and will help in diagnosing low-gain faults.

Dealing with the audio stage first, the TR-63 goes into clipping at 20mW, with a THD of 8.5%. At 10mW, its distortion is 6% and the -3dB frequency response from volume control to speaker is 290Hz - 5.9kHz, with a peak at around 1.3kHz. From antenna to speaker, it's 290~3000Hz.

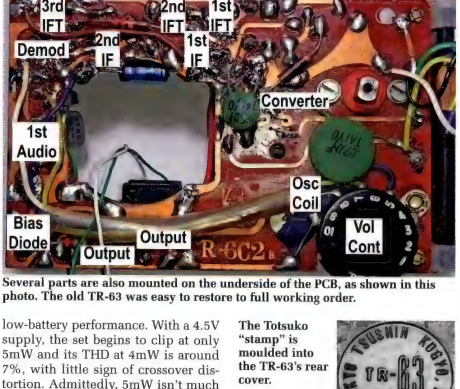
The diode biasing circuit used in the output stage contributes to the low-battery performance. With a 4.5V supply, the set begins to clip at only 5mW and its THD at 4mW is around 7%, with little sign of crossover distortion. Admittedly, 5mW isn't much but the set is still working perfectly when the battery is down to 4.5V. Of course, it's only delivering one-quarter the power output at half supply but its low-battery performance is excellent and anticipates sets such as the Pye Jetliner.

Because the set begins to clip at around 20mW output, the following RF/IF measurements have been taken at 10mW output. The RF bandwidth is ±3.7kHz at -3dB and ±55 kHz at -60dB. The AGC is quite effective and limits the output to an increase of just 6dB in response to a 26dB signal increase.

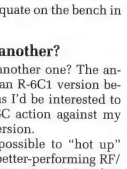
The received signal performance is quite good, though with poor S/N ratios. At full gain, for 10mW output, my modified TR-63 needs 200µV/m at 600kHz and 110µV/m at 1400kHz. However, both these figures result in an S/N ratio of only about 5dB.

The set's early AGC detracts from the 20dB S/N ratio figures, so I've opted for 15dB. This demands an input of around 700µV/m at 600kHz and 500µV/m at 1400kHz. In this set, however, I had replaced transistor X2 with a higher-performing substitute (as mentioned), so you can expect an unmodified TR-63 to have around half the above sensitivity figures.

With only 20mW of audio output at clipping, is it good enough? The answer is that while you'd need to use the plug-in earphone at the football,



Several parts are also mounted on the underside of the PCB, as shown in this photo. The old TR-63 was easy to restore to full working order.



The Totsuko "stamp" is moulded into the TR-63's rear cover.

it's perfectly adequate on the bench in my 130m² shed.

Would I buy another?

Would I buy another one? The answer is "yes" if an R-6C1 version became available as I'd be interested to compare it's AGC action against my current R-6C2 version.

Finally, is it possible to "hot up" an old set with better-performing RF/converter and IF transistors? Sure but that's not the point. Repair necessities aside, these are old radios and it's best to keep them in original condition.

Further Reading

(1) Many online sites describe the TR-63. For a thorough description, see James J. Butters' fine site at: http://www.jamesbutters.com/sonytr63.htm
(2) For a tear-down and description: https://www.ifixit.com/Teardown/Sony+TR-63+Transistor+Radio+Teardown/1219
(3) A photo catalog is at: https://www.flickr.com/photos/transistor_radios/sets/72157603553111543/
(4) Ernst Erb's Radio Museum: http://www.radiomuseum.org/r/sony_tr63_tr_63_tr_63.html (6C1, 6C2) and http://www.radiomuseum.org/r/sony_transistor_si_tr_63a.html (6C1) SC

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		PIC16F1459-I/P	USB Data Logger (Dec10-Feb11)
	PC Birdies * 2 chips – $15 pair* (Aug13), Driveway Monitor Receiver (July15)	**PIC16LF14K22**	Digital Spirit Level (Aug11), G-Force Meter (Nov11)
PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)	**PIC32MX795F512H-80I/PT**	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12), Touchscreen Audio Recorder (Jun/Jul 14)
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13), Auto Headlight Controller (Oct13) 10A 230V Motor Speed Controller (Feb14)	**PIC32MX170F256B-50I/SP**	Micromite Mk2 (Jan15) – *also includes* ***FREE*** *47µF tantalum capacitor*
		PIC32MX170F256B-I/SP	Low Frequency Distortion Analyser (Apr15) Bad Vibes (June 15)
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11), Quizzical (Oct11) Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13), Nicad/NiMH Burp Charger (Mar14) Remote Mains Timer (Nov14), Driveway Monitor Transmitter (Jul15) Fingerprint Scanner (Nov15)	**PIC32MX170F256D-50I?/PT**	44-pin Micromite Mk2 (Now with Mk2 Firmware at no extra cost)
		PIC32MX250F128B-I/SP	GPS Tracker (Nov13) Micromite ASCII Video Terminal (Jul14)
		PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14), Digital Effects Unit (Oct14)
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13)	**dsPIC33FJ128GP802-I/SP**	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11), Digital Audio Delay (Dec11) Level (Sep11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)
PIC16LF88-I/SO	LED Ladybird (Apr13)		
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun09), Lab Digital Pot (Jul10) Semtest (Feb-May12)	**dsPIC33FJ64MC802-E/P**	Inductor Motion Speed Controller (revised) (Aug13)
		dsPIC33FJ128GP306-I/PT	CLASSIC DAC (Feb-May 13)
PIC18F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)	**ATTiny861**	VVA Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11)
PIC18F45K80	USB Power Monitor (Dec12)	**ATTiny2313**	Remote-Controlled Timer (Aug10)
PIC18F4550-I/P	GPS Car Computer (Jan10), GPS Boat Computer (Oct10)		

When ordering, be sure to nominate BOTH the micro required AND the project for which it must be programmed.

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NEW: VALVE STEREO PREAMPLIFIER – (Jan 16) **$30.00**
100µH SMD inductor, 3x tree-profile 400V capacitors & 0.33Ω resistor

ARDUINO-BASED ECG SHIELD – all SMD components *(Oct 15)* **$25.00**

ULTRA LD Mk 4 – plastic sewing machine bobbin for LZ – pack 2 *(Oct 15)* **$2.00**

VOLTAGE/CURRENT/RESISTANCE REFERENCE – all SMD components# *(Aug 15)* **$12.50**
includes precision resistor. Specify either 1.8V or 2.5V

MINI USB SWITCHMODE REGULATOR all SMD components *(July 15)* **$10.00**

BAD VIBES INFRASOUND SNOOPER – TDA1543 16-bit Stereo DAC IC *(Jun 15)* **$2.50**

BALANCED INPUT ATTENUATOR – all SMD components inc 12 NE5532D ICs, 8 SMD diodes, SMD caps, polypropylene caps plus all 0.1% resistors (SMD & through-hole) *(May 15)* **$65.00**

APPLIANCE INSULATION TESTER - 600V logic-level Mosfet. 5 x HV resistors: *(Apr15)* **$10.00**

ISOLATED HIGH VOLTAGE PROBE - Hard-to-get parts pack: *(Jan15)* **$40.00**
all ICs, 1N5711 diodes, LED, high-voltage capacitors & resistors:

CDI – Hard-to-get parts pack: Transformer components (excluding wire), *(Dec 14)* **$40.00**
all ICs, Mosfets, UF4007 diodes, 1µF X2 capacitor:

CURRAWONG AMPLIFIER Hard-to-get parts pack: *(Dec 14)* **$50.00**
LM1084IT-ADJ, KCS6603D, 3 x STX0560, 5 x blue 3mm LEDs, 5 x 39µF 400V low profile capacitors

ONE-CHIP AMPLIFIER - All SMD parts *(Nov 14)* **$15.00**

DIGITAL EFFECTS UNIT WM8371 DAC IC & SMD Capacitors *[Same components also suit Stereo Echo & Reverb, Feb14 & Dual Channel Audio Delay Nov 14]* *(Oct14)* **$25.00**

AD8038ARZ Video Amplifier ICs (SMD)
For Active Differential Probe (Pack of 3) *(Sept 14)* **$12.50**

44-PIN MICROMITE Complete kit inc PCB, micro etc *(Aug14)* **$35.00**

MAINS FAN SPEED CONTROLLER - AOT11N60L 600V Mosfet *(May14)* **$5.00**

RGB LED STRIP DRIVER - all SMD parts and BSO150N03 Mosfets. *(May14)* **$20.00**
Does not include micro (see above) nor parts listed as "optional"

HYBRID BENCH SUPPLY - all SMD parts, 3 x BCM856DS & L2/L3 *(May 14)* **$45.00**

USB/RS232C ADAPTOR MCP2200 USB/Serial converter IC *(Apr14)* **$7.50**

NICAD/NIMH BURP CHARGER *(Mar14)* **$7.50**
1 SPD15P10 P-channel logic Mosfet & 1 IPP230N06L3 *N*-channel logic Mosfet

10A 230V AC MOTOR SPEED CONTROLLER *(Feb14)* **$45.00**
40A IGBT, 30A Fast Recovery Diode, IR2125 Driver and NTC Thermistor

GPS Tracker MCP16301 SMD regulator IC and 15µH inductor *(Nov13)* **$5.00**

SMD parts for SiDRADIO *(Oct13)* **$20.00**
Same as LF-UF Upconverter parts but includes 5V relay and BF998 dual-gate Mosfet.

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*All items subject to availability. Prices valid for month of magazine issue only. All prices in Australian dollars and included GST where applicable. # P&P prices are within Australia. Q'seas? Please email for a quote

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB only – *not a full kit.* If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
ULTRA-LD MK2 AMPLIFIER UPGRADE	SEP 2011	01209111	$5.00
ULTRA-LD MK3 AMPLIFIER POWER SUPPLY	SEP 2011	01109111	$15.00
HIFI STEREO HEADPHONE AMPLIFIER	SEP 2011	01309111	$20.00
SPS FREQUENCY REFERENCE (IMPROVED)	SEP 2011	04103031	$30.00
HEARING LOOP RECEIVER/NECK COUPLER	SEP 2011	01209101	$10.00
DIGITAL LIGHTING CONTROLLER LED SLAVE	OCT 2011	16110111	$30.00
USB MIDIMATE	OCT 2011	23110111	$25.00
QUIZZICAL QUIZ GAME	OCT 2011	08110111	$25.00
ULTRA-LD MK3 PREAMP & REMOTE VOL CONTROL	NOV 2011	01111111	$30.00
ULTRA-LD MK3 INPUT SWITCHING MODULE	NOV 2011	01111112	$20.00
ULTRA-LD MK3 SWITCH MODULE	NOV 2011	01111113	$10.00
ZENER DIODE TESTER	NOV 2011	04111111	$20.00
MINIMAXIMITE	NOV 2011	07111111	$10.00
ADJUSTABLE REGULATED POWER SUPPLY	DEC 2011	18112111	$5.00
DIGITAL AUDIO DELAY	DEC 2011	01212111	$25.00
DIGITAL AUDIO DELAY Front & Rear Panels	DEC 2011	01212112/3	$20 per set
AM RADIO	JAN 2012	06101121	$10.00
STEREO AUDIO COMPRESSOR	JAN 2012	01201121	$30.00
STEREO AUDIO COMPRESSOR FRONT & REAR PANELS	JAN 2012	01201121P1/2	$20.00
3-INPUT AUDIO SELECTOR (SET OF 2 BOARDS)	JAN 2012	01101121/2	$30 per set
CRYSTAL DAC	FEB 2012	01102121	$20.00
SWITCHING REGULATOR	FEB 2012	18102121	$5.00
SEMTEST LOWER BOARD	MAR 2012	04103121	$40.00
SEMTEST UPPER BOARD	MAR 2012	04103122	$40.00
SEMTEST FRONT PANEL	MAR 2012	04103123	$75.00
INTERPLANETARY VOICE	MAR 2012	08102121	$10.00
12/24V 3-STAGE MPPT SOLAR CHARGER REV.A	MAR 2012	14102112	$20.00
SOFT START SUPPRESSOR	APR 2012	10104121	$10.00
RESISTANCE DECADE BOX	APR 2012	04104121	$20.00
RESISTANCE DECADE BOX PANEL/LID	APR 2012	04104122	$20.00
1.5kW INDUCTION MOTOR SPEED CONT. (New V2 PCB)	APR (DEC) 2012	10105122	$35.00
HIGH TEMPERATURE THERMOMETER MAIN PCB	JUNE 2012	21105121	$30.00
HIGH TEMPERATURE THERMOMETER Front & Rear Panels	MAY 2012	21105122/3	$20 per set
MIX-ITI 4 CHANNEL MIXER	JUNE 2012	01106121	$20.00
PIC/AVR PROGRAMMING ADAPTOR BOARD	JUNE 2012	24105121	$30.00
CRAZY CRICKET/FREAKY FROG	JUNE 2012	08109121	$10.00
CAPACITANCE DECADE BOX	JULY 2012	04106121	$20.00
CAPACITANCE DECADE BOX PANEL/LID	JULY 2012	04106122	$20.00
WIDEBAND OXYGEN CONTROLLER MK2	JULY 2012	05106121	$30.00
WIDEBAND OXYGEN CONTROLLER MK2 DISPLAY BOARD	JULY 2012	05106122	$10.00
SOFT STARTER FOR POWER TOOLS	JULY 2012	10107121	$10.00
DRIVEWAY SENTRY MK2	AUG 2012	03107121	$20.00
MAINS TIMER	AUG 2012	10108121	$10.00
CURRENT ADAPTOR FOR SCOPES AND DMMS	AUG 2012	14108121	$20.00
USB VIRTUAL INSTRUMENT INTERFACE	SEPT 2012	24109121	$30.00
USB VIRTUAL INSTRUMENT INT. FRONT PANEL	SEPT 2012	24109122	$30.00
BARKING DOG BLASTER	SEPT 2012	25108121	$20.00
COLOUR MAXIMITE	SEPT 2012	07109121	$20.00
SOUND EFFECTS GENERATOR	SEPT 2012	09109121	$10.00
NICK-OFF PROXIMITY ALARM	OCT 2012	03110121	$5.00
DCC REVERSE LOOP CONTROLLER	OCT 2012	09110121	$10.00
LED MUSICOLOUR	NOV 2012	16110121	$25.00
LED MUSICOLOUR Front & Rear Panels	NOV 2012	16110122	$20 per set
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$30.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
USB POWER MONITOR	DEC 2012	04109121	$10.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
GARBAGE/RECYCLING BIN REMINDER	JAN 2013	19111121	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103121	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-433MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JUL 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMS	AUG 2013	04107131	$10.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp (Sept11)	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above)			(May 2013)
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
LF1 Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
VALVE SOUND SIMULATOR PCB	AUG 2014	01106141	$15.00
VALVE SOUND SIMULATOR FRONT PANEL (BLUE)	AUG 2014	01106142	$10.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THERMEIM MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THERMEIM PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111142	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	-	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101144	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00

NEW THIS MONTH

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This is arguably the handiest tool anyone involved in electronic design could wish for! It avoids the need to make impedance or reactance calculations and there is no need to revise long-forgotten formulas.

Reactance Chart for easy RC, RL or LC network design

By LEO SIMPSON

With this reactance chart, you can easily check the -3dB rolloff of a simple RC (resistor-capacitor) or RL (resistor-inductor) network or find the resonant frequency of an LC (inductor-capacitor) network.

Why do we need such a tool? Sure, you can easily Google to get a calculator for almost any purpose but typically such online calculators give you a couple of fields to fill in with the known values, say, resistance or capacitance and frequency, and then you click the "Calculate" button to get the answer.

But this does not allow you to get an overall picture of how passive components such as resistors, capacitors and inductors interact to determine the frequency behaviour of circuits. For example, if you look at a typical amplifier circuit, it is not the active components such as op amps, transistors or Mosfets which largely determine the frequency response, it is the interaction of the above mentioned passive components.

For example, in the very simplified circuit of a complementary symmetry amplifier in Fig.1, the low frequency rolloff is determined by the interaction of resistor R1 and capacitor C1 in the input circuit and also in the negative feedback network, by R2 and C2. On the other hand, the high frequency performance is determined by the interaction of inductors, resistors and capacitors in the input and output of the amplifier.

For example, ostensibly all that resistor R1 does is to provide input bias current to transistor Q1. It also sets the voltage at the output of the amplifier (to 0V). But just as importantly, those R1 and C1 values partly determine the low frequency rolloff of the amplifier.

And capacitor C1 can also determine the ultimate signal-to-ratio of the amplifier at very low frequencies, because we need it to have a low impedance. So there is more to these simple passive components than meets the eye.

So let's look at how you can determine the impedance of any capacitor or inductor from the wall chart. First, the impedance of a capacitor at any frequency can be calculated by the formula

$Z = 1/(2\pi fC)$

where Z is the impedance in Ohms;
π i is the constant 3.1415926...;
f is the frequency in Hertz and
C is the capacitance in Farads.

Similarly, the impedance of an inductor at any frequency can be calculated by the formula

$Z = 2\pi fL$

where L is the inductance in Henries and f is the frequency in Hertz.

You can calculate impedances to your heart's content using the above formulas but let us transfer the process to the reactance chart of Fig.2 (opposite), with a few examples. Say you want to know the impedance of a 100nF (100 nanofarads or 0.1μF) capacitor at a frequency of 1kHz. We have highlighted in red how you read the values off the chart, in Fig.7.

The first step is to find the value of 100nF on the right-hand vertical axis. Then you trace down the line at 45° to where it intersects the horizontal line for 10kHz which again is marked on the right-hand vertical axis. You then take a vertical (red) line down from that "intersection" to the horizontal axis. The value shown where the red line intersects that horizontal axis is about 1.6kΩ (the calculated impedance is actually 1.592kΩ). So the three steps in this process are shown as red lines on the reduced chart of Fig.7.

Note that all the axes on this chart are logarithmic and this means that when you are interpolating values between actual printed lines, the value you read off the respective axis is always a bit of a guesstimate. That's

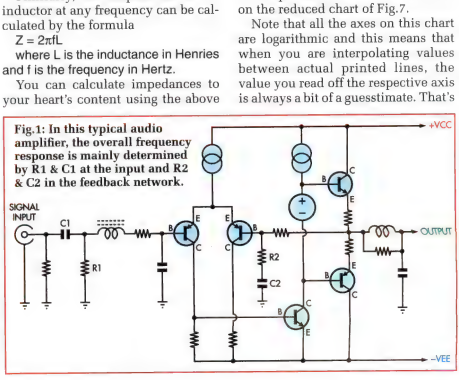

Fig.1: In this typical audio amplifier, the overall frequency response is mainly determined by R1 & C1 at the input and R2 & C2 in the feedback network.

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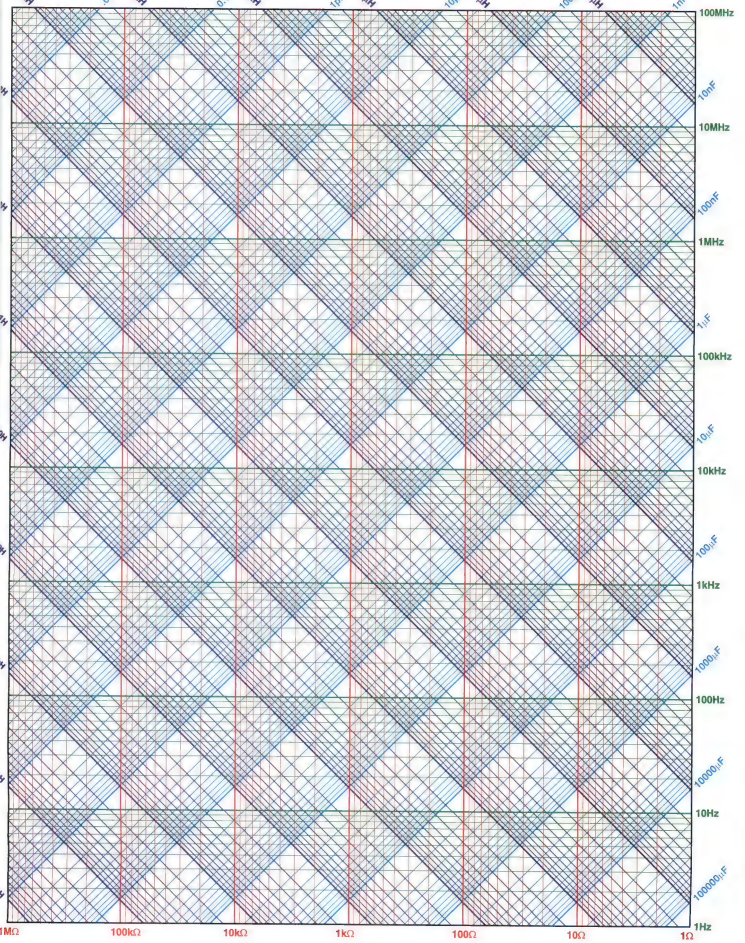
REACTANCE - INDUCTANCE - CAPACITANCE - FREQUENCY

READY RECKONER



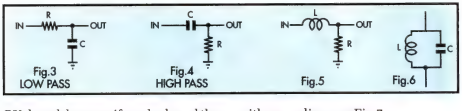


Fig.3 LOW PASS

Fig.4 HIGH PASS

Fig.5

Fig.6

OK though because if you had used the formula to calculate the precise value, you would always round it off when selecting an actual component value for a circuit. Which brings us to the next example.

Say you need to come up with a simple RC filter which will roll off frequencies above 20kHz (the -3dB point) and then roll off at -6dB octave above that point. This is the simplest possible "low pass" filter, meaning that it passes low frequencies and attenuates (rolls off) higher frequencies. The circuit is shown in Fig.3.

So if the resistor value R is known to be 8kΩ and the wanted cut-off frequency is 20kHz, you take a vertical line (green) up from the 8kΩ mark on the horizontal axis until it meets the horizontal line corresponding to a frequency of 20kHz on the right-hand vertical axis. You then take a line up at 45° until it meets the top horizontal axis which corresponds to a value of a whisker over 1nF.

(The calculated value is 992pF or almost exactly one nanofarad. We have shown three steps in this process with green lines on Fig.7.

You can use a similar process when working with "high pass" filters and in the simplest case, the positions of the resistor and capacitor in the circuit of Fig.3 are swapped to give the circuit in Fig.4. In this case, the circuit passes high frequencies and progressively blocks lower frequencies due to the impedance of the capacitor increasing as the frequency is reduced.

Feeling adventurous? Let's take a circuit example involving an inductor and resistor, an RL network set up as a low pass filter. You will often see examples of this sort of network at the input of a preamplifier where we want to block extremely high frequencies by using a ferrite bead inductor.

In this case, if you look at the formula for the reactance of an inductor, you will realise that it rises in a linear fashion with increasing frequencies, eg, a doubling a frequency will double the reactance.

By the way, for the purpose of using this chart, the terms reactance and impedance mean the same thing. In fact, some readers would regard the term "reactance" as being obsolete.

OK, so now we have a simple RL low pass filter, as shown in the circuit of Fig.5. Let's say the value of the inductor is 500 microhenries (500μH). You can find where the 500μH line on the chart intersects the top horizontal axis – it is marked in blue and is at an angle of 45° (sloping up to the left) on the chart of Fig.7.

In fact all the inductance lines slope up to the left in the same way, just as all the capacitance lines slope up the to right. If we project that line down to the horizontal line for a frequency of 10MHz and then project down from the intersection of those two lines down to the bottom line of the chart and the impedance can be read off as just over 30kΩ (actually 31.4kΩ).

That's fine, but what would be the result if the circuit of Fig.5 used a 500μH inductor and a resistor value of 1kΩ? What would be the cut-off frequency. In this case, we take the same 500μH sloping line and intersect it with the 1kΩ vertical line. In this case, the two lines intersect at a point corresponding to a frequency of just over 300kHz (actually, 318kHz).

Finally, let's find the resonant frequency of a parallel LC network, as shown in Fig.6. In this case, we will use an inductor of 200 millihenries (200mH) and a capacitor of 2 microfarads (2μF). In this case we need to find the intersection of the sloping line for a value of 200mH with the sloping line for a value of 2μF. Both lines are shown in pink and you will see that if you project across to the right from their intersection, you can read the resonant frequency from the vertical right-hand axis as 250Hz (on Fig.7).

As you can see, this chart enables you make many thousands of impedance, resistance, capacitance or frequency calculations, all without resorting to formulas or calculators. SC

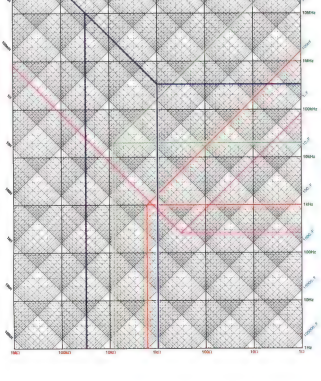


Fig.7: the coloured lines on this example of the reactance chart demonstrate examples (see text) of how you can find the impedance of a capacitor or inductor, the cut-off frequency of a simple RC or RL network or the resonant frequency of a series or parallel-tuned LC circuit. Many other impedance calculation can by done by a similar two or 3-step process.

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Excessive voltage for SC480 amplifier

I have a couple of SC480 amplifiers which I have assembled into a chassis. However, when it comes to obtaining a power transformer, it seems virtually impossible to get a 56VAC centre-tapped toroid. I have probably erred on the wrong side of safety by purchasing a 30-0-30VAC transformer instead of perhaps a 25-0-25VAC one.

Actually, my decision was partly based on the fact Altronics were dumping these for $49 (RRP $110). This of course is a Powertran toroid and has the auxiliary windings also so I couldn't resist this deal and the budget was limited anyway.

The rectified voltage is 44V DC or very nearly 45V DC depending on mains fluctuation but I have not seen it at less than 43V DC; even with the amplifier wound up fully (pretty good regulation). This voltage is pretty stable as I had the transformer sitting in the chassis and measured with and without the modules installed and found next to no variation on AC or DC output.

The question is how long will the amplifier modules handle this overdesign voltage and what, if anything, short of replacing the transformer, should I consider doing to help this situation? Mind you, the amplifiers don't seem to be bothered by this. Nothing is getting excessively hot or distorting or cutting out.

I shut all the doors and windows and cranked it up with some pretty heavy material one afternoon and they delivered some pretty high levels for a couple of hours, with no ill effects. It was hottish but that was to be expected (my ears fared worse than the amplifiers, I fear!).

I know that means some components are probably under more stress than designed for and so will probably fail eventually, which I don't really want to happen. To all intents and purposes, the old SC480s are not the worst amplifiers in the world (pretty good, actually). (D. L., via email).

- The amplifier could survive for years at this higher voltage but you never know. It depends on how high your mains voltage goes.

One way to ensure that the voltage is not excessive would be to build our Mains Moderator project from the March 2011 issue. In essence, this was a step-down auto-transformer to reduce the incoming mains voltage by about 30VAC.

You can see a free 2-page preview of the article at www.siliconchip.com.au/Issue/2011/March/Mains+Moderator%3A+Stepping+Down+The+Volts

Query on power transformer wiring

My query concerns the 0V, 12V and 15VAC secondary windings of the Altronics MC5540 toroid transformer that I am using with the Ultra-LD Mk3 power supply to power the Class-D amplifier from the November & December 2012 issues. I am using this power supply to run two of the amplifiers in bridge mode, to drive a 12-inch, 8-ohm 200W subwoofer.

As stated in the Ultra-LD Mk3 article, for the 15V lines to operate, each of the unused 12V leads had to be cut and then the two wires inside the sheath rejoined and soldered back together. The two 12V lines are then separately covered in heatshrink tube.

As I will only be requiring the 40VAC and 0V lines, I would appreci-

Using The DC Speed Controller As A Welding Power Controller

Regarding the 12/24V 20A DC Motor Speed Controller Mk.2 of June 2011, given that Mosfets Q1 & Q2 (IRF1405) are rated at 169A, is it only the heatsinking that has limited the controller to 20A?

I'm looking at controlling the 24V lead-acid battery power that feeds a portable MIG welder, to weld thin sheets of steel. The manufacturer of the welder suggests, for this purpose, 18V, consisting of 12V and 6V batteries linked in series and/or increasing the resistance in the power and/or ground leads by lengthening them.

The option with the 6V battery raises the problem of charging it, as I haven't seen any intelligent 6V battery charge regulators. I have a rough figure that I would be drawing a maximum of 30A for the type of welding under consideration.

Could the DC Motor Speed Controller do the job if the Mosfets were put on bigger heatsinks off the PCB? What about D1, the MBR20100CT dual 10A 100V Schottky diode? Will it need to be upgraded or doubled in parallel and mounted on a larger heatsink off the PCB as well?

Alternatively, have you designed and published a more appropriate device that would better suit my needs? (C. B., Bonville, NSW).

- The main determinant of the 20A rating is the thickness of the PCB tracks that may fuse with higher current and the screw terminal ratings. You could mount the Mosfets off the PCB and use sufficiently-rated wiring for the Drain and Source connections. The remainder of the controller circuitry would then be just used in the gate drive to the Mosfets and with a common ground connection back to the Mosfet source.

You should parallel a few Mosfets so as to share the load, using separate gate resistors to drive each one. Diode D1 is for limiting back-EMF when driving an inductive load. The MBR2010 should still be suitable as it is not carrying the MIG welder load.

Mazda Instant Start Explained

I don't know if this would interest everyone but I for one would like a brief outline on how non-hybrid car engines achieve instant starting, eg, the Mazda 3.

I understand that with a hybrid car, the generator can also be used as a starter motor to instantly start the engine, ie, a high-torque direct-connected electric generator acting in reverse as a starter motor. But a Mazda 3 and other similar non-electric vehicles have this feature whereby if you are stopped for longer than about five seconds in traffic, the engine stops. The moment you take your foot off the brake, it springs instantly back to life. How do they do this without the engine winding over on the starter motor like most engines do?

Why can't this method be employed 100% all the time on a warm engine even when you get back into the car after leaving it for a short while? I can understand it might be too savage on a cold motor in the morning with drained oil back to the sump etc, but above a certain temperature why can it not be used all the time? I would love to know exactly how they achieve this instant starting. (S. S., via email).

● That's an interesting question. We used Google to find the answer and what follows is largely a quote from a Mazda website.

"It's Mazda's i-stop system which uses a 'combustion start method' to restart the engine. The starter motor is briefly engaged to rotate the engine precisely so that one piston is positioned just beyond top dead centre and then fuel is injected into the cylinder and ignited. It injects fuel directly into a cylinder of the stopped engine and ignites it to force the piston down. Because the combustion start method requires the pistons to be halted in the optimum position when the engine is stopped, this system requires technology capable of accurately detecting and controlling piston positions.

The starter motor is operated to assist engine restarting but using mainly combustion power for restarting requires less time and reduces power consumption.

This unique technology achieves an engine restart time of 0.35 seconds, the best in its class (automatic transmission vehicles, based on in-house measurements). As the engine starts, the brake is immediately released and the car can move again quickly. Due to the rapid restart, this system does not inconvenience the driver, which is vital in situations such as turning across an oncoming lane of traffic at a traffic light.

The i-stop system does not require any extra work by the driver, and achieves an approximate 10% improvement in fuel economy (Axela class, Japanese 10-15 mode test cycle) by precisely stopping the engine for short periods."

As far as we know, the Mazda uses a starter motor/alternator which is directly geared to the flywheel, which would be necessary in order to stop a piston in precisely the correct position to allow fuel to be injected and ignited for the quick restart.

By the way, there is nothing inherently new in this idea. Apparently, it was known in the days before cars had starter motors and they had to be cranked by hand. It was reported to be quite effective on those engines which had "trembler" ignition.

The idea was that if fuel was injected, the engine cranked (by hand) to just the right position, and then the ignition turned on, the engine would start.

We think it was probably "hit-or-miss"!

ate your advice as what to do with the 0V, 12V and 15VAC secondary lines to avoid any possible shorting out of the live voltage of the 12V and 15V lines. From the article, my thoughts would be to do the same with the 15V and 0V lines.

Is this acceptable or will it cause problems with the operation of the transformer? (D. W., via email).

● Yes, the spare 12V and 15V windings can be insulated with heatshrink tubing. The transformer will provide 12VAC and 15VAC at the windings but this will not affect operation for the 40VAC output.

Adjustable current sink for valve biasing

I build valve guitar amplifiers as a hobby and as a small side-business. My most common power amplifier is a single-ended, class A design using only one octal power valve. As per the majority of these designs it is cathode-biased.

In order to maximise the choice of octal valves (6L6, KT88, KT66, EL34, 6V6, 6550), I connect a 180Ω 5W resistor in series with a 1kΩ 3W wirewound potentiometer between the cathode of the power valve and earth. The 1kΩ pot allows the amplifier to be biased correctly using any of the octal valve choices.

The supply to the plate (anode) is around 400V DC and the maximum current through the cathode is around 80mA. While it seems that everything is working OK and the 3W rating of the pot is within operating limits, my concern is that this wirewound potentiometer is directly interconnected to the supply of the HV signal that feeds the audio output transformer and all the HV primary current is driving through this pot.

Also, there is a scratchy sound heard when the bias is adjusted. I am hoping I can replace this 1kΩ pot with some form of electronic variable resistor design where a semiconductor device is controlled by a low rating pot and the semiconductor is configured to act like a variable resistor. Has Silicon Chip done something like this? The maximum rating of any common pot design is around 3W.

A design like this could also increase the power rating. For my application, I have many sources of voltage supply, including a 12V DC supply I use for the switching circuits. (J. C., Point Cook, Vic).

● What you are looking for is essentially an adjustable current sink which can ideally be set for current and voltage – or think of it as an adjustable shunt regulator or a DC electronic load. Either way, the circuit is going to be a lot more complicated than your 1kΩ 3W pot in series with a 180Ω resistor.

We have published a 50W electronic load in the September 2002 issue; see

a 2-page preview at www.siliconchip.com.au/Issue/2002/September/50-Watt+DC+Electronic+Load

Ferrite bead specification

I am in the process of obtaining the parts to build the Ultra-LD Mk4 200W Amplifier module, as described in the August & September 2015 issues. However, the listing for inductor L1 in the parts list on page 38 appears to be missing some information. It just specifies an SMD 3216/1206 ferrite bead.

I can't find any information in the articles for this part. I presume this is an oversight. There is no Digi-Key ID given and there appear to be thousands of these listed on Digi-Key's website. Can you help please? (T. G., via email).

● The ferrite bead isn't terribly critical. Pretty much any bead will give significant attenuation at radio frequencies while passing audio frequencies through essentially unchanged.

On the basis that the highest possible impedance in the FM band is a good thing, we would recommend Digi-Key 240-2548-1-ND (Laird HZ-1206E152R-10). This should give very high attenuation in the 50-250MHz region and significant attenuation out to several GHz, which should also help filter out any digital 2.4GHz signals which may be picked up by the wiring.

Simplifying the high-voltage probe circuit

I have a few question about the Isolating High Voltage Probe in the January 2015 issue. Are IC1a and IC1b the same? Also are the IC2a/b the same? In addition, I am not using the division settings (the different resistor values) so if I buy the PCB, would I still be able to skip this or they are connected to the rest of the circuit? (A. A., via email).

● IC1a and IC1b are two (mostly) separate devices contained within the one IC package. They share the power supply but otherwise operate independently. The situation is the same with IC2a and IC2b.

You could connect signals directly between pin 3 of IC1a and CON2 however you would need a series resistor to prevent damage to IC1 in case the signal was more than 4V in either polarity. This would limit the device to operate correctly only with a signal of up to 4V peak.

Electrolytic Capacitor Reformer & Tester

I have bought the article, PCB and programmed PIC for the Electrolytic Capacitor Reformer & Tester (Silicon Chip, August & September 2010). However, before building any circuit I like to understand how it is intended to work. I believe there may be an error in the divider resistor chain values that control the output of the inverter.

Consider S1 set for 10V (the parallel divider chain is not in circuit). The divider is composed of (4 x 75kΩ) 300kΩ + VR1 (at midpoint) 25kΩ in series with 100kΩ. This gives a division ratio of 100/425 = 0.235. IC1 regulates with 1.25V on pin 5 so this would set the output of D4 at 5.3V not 10V.

To set 10V would require the 100kΩ resistor (in parallel with zener diode ZD2) to be 47kΩ. Is this correct? If so, the resistors in the rest of the divider (around S1) are incorrect. (N. F., via email).

● Your calculations are fine as far as they go but you are forgetting the input bias current of the Cin- (comparator) input of the MC34063 and also the leakage current of ZD2, at an applied voltage of 1.25V. When these additional currents are taken into account, the converter's output voltage with switch S1 in the "10V" position can be set to a value of 10V as claimed.

It's because of the within-tolerance variations of these "hidden" currents that we included trimpot VR1 in the upper leg of the divider.

V8 sound generator for quiet cars

I have a suggested construction project for petrol heads with quiet cars – a V8 noise generator with the sound fed through (fake) exhaust pipes and through the car's sound system. This would be much cheaper than installing straight-through exhausts and more effective anyway, if you only have a small 4-cylinder engine. It might also be a safety feature, as pedestrians will hear the car coming. Perhaps this would be a good article to feature in the up-coming April issue? (K. P., via email)

● As a matter of fact, we did a V8 Doorbell project in the January 2005 issue. This could possibly be modified and controlled by the tachometer signal and throttle position sensor in typical cars, to vary the apparent revs and loudness.

Checking software for the Induction Motor Speed Controller

I am learning about motor speed control and your articles from April-May 2012 have been a great help. I have created a test circuit on a breadboard (ignoring the high power part) however when using the latest version of the firmware (1010512B.hex), I am unable to get any output.

At this point, I suspect the changes for heatsink temperature detection of over 60°C may be at fault but without the previous version of the firmware it would be pretty hard to confirm it. Is there any way to get a version of the firmware prior to the changes from August 2013? (C. N., via email).

● It should be possible to make your version of the software work, despite the fact that you may not have the optocouplers and IC1 connected. However, all the inputs to IC3 must be connected and pin 23 should be held high, in the absence of OPTO1.

Modifying an AM radio to receive FM

Have you ever designed a method of converting an AM radio to receive the FM band, say 98-108MHz. This would involve mounting a toggle switch on the rear to switch the audio over and a supply to the board (say from the 6.3V heater) when FM is used.

It could use a Philips FM receiver chip and the local AM oscillator unmodified to tune this FM chip, say, via a frequency divider to voltage converter.

I would like a board capable of being installed under the chassis with one new aerial wire out the back. (B. S., via email).

● The simplest way to add FM reception would be to use a Philips TDA FM receiver chip. However, there is no easy way to tune it over the FM band

Headlight Protector To Stop Bulb Failures

A friend has asked me if there was anything available to wire into his car to guarantee the voltage to low beam does not rise above 12.5V. It seems this car is plagued with an ongoing fault of failing headlight lamps. They don't last a year and repeated trips to the auto electrical shop have found nothing.

It seems that there is nothing out there that one can buy off the shelf: a simple 12-15V in/12V maximum out? Can Silicon Chip help with a basic circuit that can regulate the voltage to 12.5V and be able to handle 120W all day long?

I note numerous regulator circuits with multiple bypass transistors to get the amps required. Surely, there's a simple circuit that uses only a few components that can be set in resin and mounted on the firewall? I am after simplicity in design and something that is bulletproof. Price is secondary. (P. L., via email).

● You could use the Automatic Car Headlight Controller, as published in October 2013. This can reduce the average voltage applied to the headlamps. The project would be used so that when the headlights are switched on, this would power the Automatic Car Headlight Controller so that this then powered the headlights.

This would be using the project in a different manner to that intended, where daytime running lights would be on with reduced brightness during the day but bypassed to drive the headlights on fully when switched on. You would just need to wire the Automatic Car Headlight Controller so that it ran as daylight driving lights when powered up and with the brightness adjusted to produce the desired average voltage applied to the headlamps. The light dependent resistor that detects day and night could be replaced with a 100Ω resistor to ensure that "daytime operation" is permanent.

However, you should check the output voltage of your alternator, although the auto electrician should have done this as a matter of course. Repeatedly blowing bulbs is a classic symptom of excessive voltage from the alternator. Usually, the only cure is to replace the alternator.

(88-108MHz) with a variable DC voltage. We did publish a circuit for this back in November 1992 but the PCB is no longer available.

Organ service manual wanted

I have been trying to repair a Baldwin Fantasia Fun Machine Model 150 organ. I have not been able to procure a service manual (preferred) in either PDF form or schematic form. If any of your readers could assist me with one, I would be very grateful. Please contact Sib at sib_erna@hotmail.com

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Crystal DAC upgrade with improved filter

I am considering upgrading my Crystal DAC featured in the February 2012 issue to the Classic DAC circuit from the February to March 2013 issues. I was reading the February 2013 article and spotted the explanation that the DAC's differential low-pass output filter circuit has been revised to be much better than the Crystal DAC, as the values used in the Crystal DAC were found to not provide as good filtering.

As the only things that changed between the two DACs in the circuit are the values of the components, would it be recommended to use the values from the Classic DAC filter circuit when building the Crystal DAC to improve the performance? (T. K., via email).

● That would be a good idea. While you may not notice a substantial audible difference, in theory the values used in the CLASSiC DAC are better suited, so you might as well use the same configuration.

Speed control for a 240VAC motor

Do you have a 240VAC motor speed controller? I want run a mains-powered motor over a range of speeds, from full speed to quite slow. Can this be done? (J. T., via email).

● Over the years, we have published many motor speed controllers to run 240VAC motors. However, the first thing to know is that there are three general types of motor which run from the 240VAC (now 230VAC) 50Hz mains.

The first type is those with brushes, generally referred to as "universal motors" (because they can actually run from DC or AC supplies). Most portable appliances such as power tools (drills, circular saws, routers, whipper snippers, vacuum cleaners and kitchen appliances such as food mixers and blenders) use universal motors and they can have their speed varied over quite a wide range by relatively simple power control circuits. Two of the most recent speed controllers to suit these motors are as follows:

(1) 10A Universal Motor Speed Controller, Mk2, February 2009. This is a basic SCR speed control which does not have maximum speed control and has a tendency to result in "cogging" if you try to using too low a speed setting on some motors; see a 2-page preview at www.siliconchip.com.au/Issue/2009/February/10A+Universal+Motor+Speed+Controller%2C+Mk.2

(2) A 230VAC/10A Speed Controller For Universal Motors, February & March 2014. This is a full-wave design and gives a very wide range of speed control without "cogging"; see a 2-page preview at www.siliconchip.com.au/Issue/2014/February/230V-10A+Speed+Controller+For+Universal+Motors%2C+Pt.1

Different types of 230VAC motors are used in portable fans and ceiling fans. The motors used in these appliances do not have brushes. They are shaded-pole motors (used in small fans) and capacitor-run induction motors (used in larger ceiling fans and some pumps). Both are variants of induction motors. Typical speed controls used for shaded poles motors are very

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Ask SILICON CHIP

. . . continued from page 94

similar to those used in Triac-based light dimmers and while they can vary the speed over quite a wide range, they can also produce quite a lot of interference to AM radio reception.

To cope with the radio interference problem, we produced a linear (ie, non-switching) design in the May 2014 project, a Deluxe 230VAC Fan Speed Controller. Essentially, this circuit rectifies the 230VAC mains and the fluctuating DC is then varied by a series Mosfet.

You can see a 2-page preview at www.siliconchip.com.au/Issue/2014/May/Deluxe+230VAC+Fan+Speed+Controller

Finally, the most common motor used where high power is required is the induction motor which has no brushes, commutator or slip-rings and relies on an induced rotating magnetic field to drive the rotor. This type of motor is essentially constant in speed as it is locked to the 50Hz mains frequency. These are commonly used in pumps, refrigerators, air-conditioners and so on.

The only practical way to control the speed of such a motor is to produce a circuit which varies its operating frequency and voltage. We have produced one such design, along with a number of revisions and additions which can all be found on our website if you search for "induction motor speed controller". However, the main design was featured in the April & May 2012 issues and was revised in the December 2012 issue. You can see a 2-page preview of the April 2012 issue at www.siliconchip.com.au/Issue/2012/April/1.5kW+Induction+Motor+Speed+Controller%2C+Pt.1 SC

Next Issue

The February 2016 issue of SILICON CHIP is due on sale in newsagents by Monday 25th January. Expect postal delivery of subscription copies in Australia between January 25th and February 5th.

Valve Preamplifier

. . . continued from page 35

Make sure nothing conductive is near the PCB and it isn't close to the edge of your bench. Then, keeping clear of the assembly, plug the power supply into mains. Within about one second of power being applied, the HT voltage should reach 285V or thereabouts and stabilise, with the green and red LEDs lit. Either way, switch off power and wait for it to discharge to a safe level (below 40V) before continuing.

If there's a fault, once the HT rail has discharged, check component placement and orientation as well as solder joint integrity.

Assuming all is well, connect regular probes to your DMM but leave it on the 300V (or higher) range. Power the board back up and measure the voltage between pins 4 and 5 on both valve sockets (see Fig.6). You should get a reading close to 12.6V. Now check the voltages at the other pins relative to GND. You should get ~285V for pins 1 and 6 and close to 0V for pins 2, 3, 7 and 8. Pin 9 is not connected to anything.

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You can now switch the power off and push the two valves into their sockets. They will be stiff, especially if this is the first time the sockets have been used. You may find it easier to gently rock them in. While you can in theory install the valves with HT voltage present, it's much safer to wait for it to decay first.

With the valves in place, power back up and check the HT voltage, using the test pads in the centre of the board. It should rise to around 270V at first and then slowly decay to around 250-260V as the valves warm up and their operating current builds.

In the unlikely event that the HT supply remains above 280V and there are no board or valve faults, this may be because component variations are causing the supply to deliver more current than it's designed to. The simple solution is to reduce the value of the 150pF capacitor to 120pF. This will increase the switchmode frequency and reduce the duty cycle and should bring the HT back in line. **If you need to do this, don't forget to wait for LED2 to go out before working on the board.**

Finally, perform a live signal test. Switch off, wait for LED2 to go out and connect a signal source to CON1/CON2 and an amplifier to CON3/CON4. Next, turn the volume right down, power on and wait 30 seconds or so for voltages to stabilise. Then press play on the signal source and slowly advance the volume until you hear clean, undistorted sound.

If the sound is distorted or missing, switch off and carefully check the component values around each valve socket as well as the solder joints.

Putting it in the case

That's all for this month. In the second and final article next month, we'll go over the details of how to put together the custom laser-cut case and fit the PCB inside it. SC

Advertising Index

Altronics 72-75
Digi-Key Corporation 5
Emona Instruments 65
Front Panel Express 9
Hare & Forbes ..... OBC
Icom Australia 17
Jaycar IFC,45-52
KCS Trade Pty Ltd 3
Keith Rippon 95
LD Electronics 95
LEDsales 95
Master Instruments 95
Ocean Controls 6
Radio & Hobbies DVD 62
Sesame Electronics 95
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Silicon Chip Online Shop 86
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Silvertone Electronics 7
Tendzone 11
Tronixlabs 8,95

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